INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: INSTRUMENT MANUFACTURING • JOURNAL OF THE SCMA • SIMULATION COUNCIL NEWSLETTER

in this issue . . .

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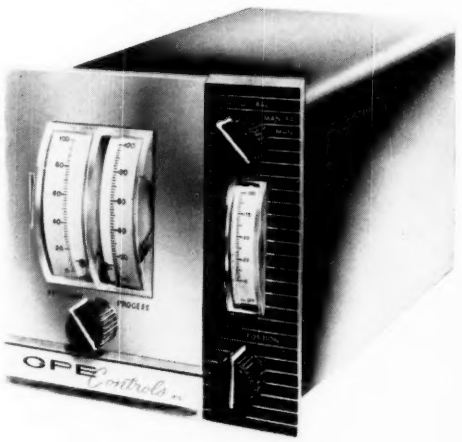
FEBRUARY 1960

Electronic controllers for high-performance systems!

The new **GPE Controls** R465 Electronic Controller is built for high performance in every aspect...the result is the **highest degree of dynamic accuracy** possible. Three times as fast as other known control systems, yet comparably priced. With GPE Controls electric transmitters and electro-hydraulic valve actuators, precise control can be maintained at more than 20 cps. Easy, low-cost installation, because high-level d.c. signal makes possible simple unshielded wiring. Instant visual comparison of parallel set-point and process variable indicators.

GPE Controls R465 Electronic Controller features advanced functional design throughout. Controller drawer (left) and manual/automatic station (right) are housed in a dustproof mounting case. Either section may be serviced while the other controls the process. Proportional band, rate, and reset controls are accessible from the front while controller is operating, and are calibrated in logarithmic steps for ease in adjusting to process dynamics.



GPE Controls | A GENERAL PRECISION COMPANY

NEW factual bulletin tells the "how and why" of electronic control. Write for your copy today!

GPE Controls, Inc. (formerly Askania Regulator Company)
240 East Ontario Street • Chicago 11, Illinois

A Subsidiary of GENERAL PRECISION EQUIPMENT CORPORATION

CIRCLE 1 ON READER-SERVICE CARD

LEWIS SELECTOR SWITCHES

for RESISTANCE THERMOMETERS

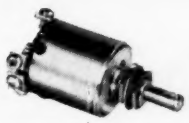
for THERMOCOUPLE THERMOMETERS

THE 9S SERIES / *The Space Savers*

Small, sturdy, steel cased switches, 1¼ inches in diameter, 2$^{9}/_{32}$ inches total shaft length, one-hole mounting with ½ inch-32 NS-2A threaded bushing. Designed especially for connecting two or more resistance bulbs to one instrument.

Part No.	Description
9S5	Single pole, four positions (with knob)
9S5B	Single pole, four positions
9S5E	Single pole, five positions
9S10	Double pole, double throw

All make before break, the instrument connected is never subjected to an open circuit during the switching operation.



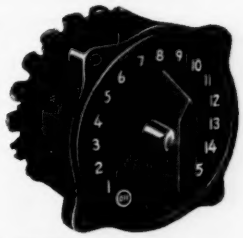
1¼ INCH SIZE

EACH SWITCH HAS "OFF" POSITION PLUS NUMBER OF POINTS LISTED.

Points	Size	Switch Part Numbers: Thermocouple Type	Switch Part Numbers: 3 Wire Resistance-Thermometer Type
2	2"	11S2	36SR2
3	2"	11S3	36SR3
4	2"	11S4	36SR4
5	3"	10S5	37SR5
6	3"	10S6	37SR6
8	3"	10S8	37SR8
9	3"	10S9	37SR9
10	3"	10S10	37SR10
12	3"	10S12	37SR12
16	3"	10S16	37SR16
18	3"	10S18	37SR18
20	3"	10S20	37SR20
24	4"	27S24B2	38SR24
28	4"	27S28B4	38SR28
40	4"	38S2C	

(No. 38S2C is made with soldering-lug terminals)

2 INCH SIZE



3 INCH SIZE

SPECIAL SWITCHES 37S6C2, Four "4-point and OFF" thermocouple switches combined in one 3" case.

The 44S Series, 2$^{9}/_{32}$ inches in diameter, shaft 2¼ inches, approx. One-hole mounting with ½ inch-32 NS-2A threaded bushing.

Part No.	Description
44S4	Six pole, double throw
44S7B	Double pole, four position
44S7B2	Double pole, double throw

For use with resistance thermometer, contacts make before break.

DESIGNED FOR TEST WORK AS WELL AS FOR PERMANENT INSTALLATIONS. LEWIS SELECTOR SWITCHES ARE CONSTRUCTED WITH STURDY CONTACTS OF LOW RESISTANCE AND POSITIVE DETENT. THESE SWITCHES ARE SPLASHPROOF, DUSTPROOF AND ARE BUILT TO GIVE YEARS OF SERVICE.

4 INCH SIZE

THE LEWIS ENGINEERING CO.

Specialists in Electrical Temperature Measurements

NAUGATUCK, CONNECTICUT

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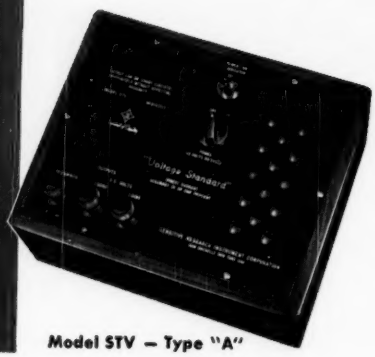


Model STV — Type "A"

D.C. VOLTAGE STANDARD

All SRIC instruments are calibrated against primary standards that have National Bureau of Standards Certificates of Accuracy and are unconditionally guaranteed for a period of one year.

The Model STV is an extremely accurate and stable reference source for use with "null balance" devices such as potentiometers and other infinite impedance comparators. It is at least equivalent in accuracy to the best unsaturated standard cells and is superior in almost all other respects to both saturated and unsaturated types.

While the Model STV is essentially a zero current drain source, it may be operated into any impedance without damage. It can be short circuited indefinitely without affecting accuracy or life expectancy, and it will almost instantaneously regain its original open circuit voltage when the short is removed. For calculating output current, the Model STV may be considered a perfect voltage source in series with a 2000 ohm resistance; thus the maximum current when short circuited is .5 ma. Special units are available for use as Standard Current sources into specific external resistances.

The accuracy of the Model STV is unaffected by vibration from transportation, exposure to extremes of temperature, or changes in operating position.

Model STV — Types C & D

Types "C" & "D" Model STV units are designed specifically for use in new or existing O.E.M. instruments. Output, accuracy and stability are exactly equivalent to Type A units.

SPECIFICATIONS — Type "C"

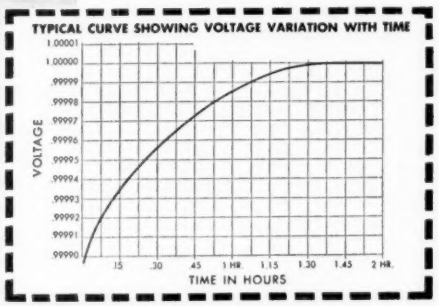
Input: 115 V.A.C. ±1%; 50-500 cps; 25 va.
Size: 3"x3"x3½" h, deep drawn aluminum case for chassis mounting.
Output: Accuracy and other specifications exactly as listed for Type "A".

Type "D"

Input: 150 Volts D.C. ±1%.
Size: Same as Type "C" above.
Output: Accuracy and other specifications exactly as listed for Type "A".

SPECIAL UNITS

Special reference sources are available with any voltage output up to 7.5 volts and for any current up to .5 ma., into specific external resistances. Correspondence is invited on special requirements.



SPECIFICATIONS — Type "A"

Input: 90-135 Volts AC; 60 cps; 25 va.
Output: 1.0000 Volt and 1.0185 Volts D.C.
Accuracy: ±.01% of nominal output (furnished with actual output certified to .001%).
Stability: ±.005% of actual output for 100-125 Volts input and 20°-30°C.
±.01% for 90-140 Volts input and 15°-35°C.
Temperature Range: 15°-35°C (Operates with reduced accuracy beyond these limits, but with its output exactly reproducible).
Operational Life: 25,000 hours minimum.
Size: 9⅛"x7⅞"x5". **Weight:** 10 lbs.

Type "B"

Rack Panel Mounting Voltage Standard. Specifications same as Type "A" except mounted on 19"x5¼"x⅜" bakelite panel.

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Symbol of Quality

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927.

CIRCLE 3 ON READER-SERVICE CARD

VOLUME 33
NUMBER 2

FEBRUARY
1960

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WITH

ONE-PLANE PRESENTATION

OUTSTANDING FEATURES

- Reliable, dependable, no moving parts.
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- All digits uniform in size and intensity... easier and faster to read.
- High-contrast viewing screen insures utmost visual sharpness.
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- Individual units may be assembled in groups for convenient panel mounting.
- Dimensions: 1-9/16" wide, 2⅝" high, 5⅝" long.

PRICE PER UNIT $18.00

QUANTITY PRICES ON REQUEST

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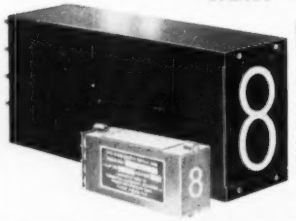
Series 80,000



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INSTRUMENTS AND CONTROL SYSTEMS

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Solid State Reliability IN A 10 mc Counter

The CMC 700 Series is the only major breakthrough in counting, timing and frequency measuring equipment in the past 10 years. Here is the first successful application of transistors to high frequency counting and timing. Transistors perform all the functions in CMC's 700 series that required 63 tubes in old style counting equipment. These are the most reliable counters ever made.

TRUE DIGITAL LOGIC CIRCUITRY

By answering an obvious need for a completely new, up-to-date approach to counting and timing instrumentation, CMC has produced solid state instruments with greatly simplified circuitry, using logic "and" and "or" gates.

LIGHT AND SMALL, LOWER POWER DRAIN

Each 700 series instrument weighs only 27 pounds, measures 7 inches high, 17 inches wide, and 14 inches deep. Power consumption is a meager 46 watts, 1/10 the amount for vacuum tube models.

DO ALL THESE JOBS

Measure frequency from dc to 10 mc, time interval from 0.1 μsec, ratio 1 cps to 1 mc and unlimited multiple period selection. Frequency converters available for higher frequencies. The counter also generates time interval marker pulses from 1 μsec to 1 second. Data can be presented on standard decades or inline Nixie tubes. The 700 series will operate digital recording equipment, punches, inline readouts, and other data handling gear.

These Features, Too—Decade count-down time base – frequency divider circuits never need adjustment. Accuracy, ±1 count ±oscillator stability. Sensitivity, 0.25 v rms; input impedance, 25 k ohms/volt.

And The Price—Higher than vacuum tube models. But you can save the difference on down time in the first year. Model 727A Universal Counter-Timer, $2,750; Model 707A Frequency-Period Meter, $2,575; Model 757A Time Interval Meter, $1,975. Rack mount optional at no extra cost. All prices f.o.b. Sylmar, California.

More Information Available – Your nearby CMC engineering representative will be happy to arrange a demonstration and provide you with complete technical information. Or you may write Department 552.

CMC 28

Computer Measurements Co.

A Division of Pacific Industries

12970 Bradley Avenue, Sylmar, California

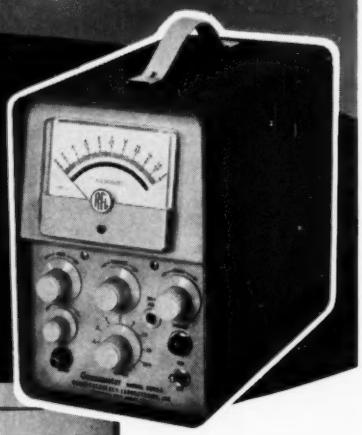
Phone: EMpire 7-2161

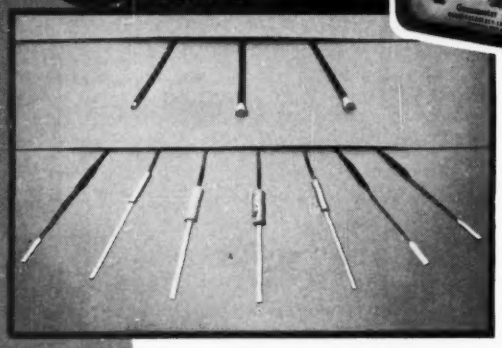
CIRCLE 5 ON READER-SERVICE CARD

Analyze Magnetic Circuits

Model 1295A provides NINE FULL-SCALE Ranges

(0 — 20K+ Gausses)





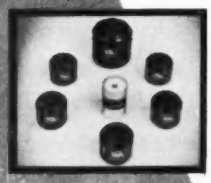
This Gaussmeter employs temperature stabilizing transistor circuits and a full set of balancing controls for fine adjustment. Readings are accurate to ±3%, repeatable within 1%; accuracy can be increased to ±1% at most points using special reference magnets. Magnetic fields from DC to 400 cps can be measured.

Ten Probes Fit Most Magnet Gaps

Each of the probes shown will work from 0 to 20K+ gausses with the Model 1295A. Since no single probe will fit all magnet configurations, a selection of Bi and InAs elements, rigid or flexible shafts, and flat or axial tips varying from .010" to 0.312" thick is available to meet most applications.

With the Model 1295A and any probe, it's easy to make direct measurements of gap flux density; analyze location, homogeneity, direction and intensity of stray fields in magnetic circuits. Formula predictions can be checked by direct measurement.

Probe Reference Magnets



The 1000-gauss ±¾% flat probe ref. magnet supplied with the Model 1295A is sufficient to maintain the ±3% system accuracy over all ranges. Other values from 200 to 10K gausses, including axial fields, are also available. All magnets are properly stabilized and shielded.

Net price of Model 1295A with reference magnet (without probe) is $390. f.o.b. Boonton, N.J. Probes from $30. to $180.

SEND FOR TECH. DATA

For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

RFL Radio Frequency LABORATORIES, INC. Boonton, New Jersey, U.S.A.

CIRCLE 6 ON READER-SERVICE CARD

I&CS LETTERS TO THE EDITOR

Editor, I&CS:

Mr. Johnson's idea of separating articles for filing purposes is excellent. I have often wondered why this is not done more often. I only hope that your example will spread to other technical publications.

Have you also considered using the Dewey decimal classification in numbering your articles and book reviews? Many European magazines have been doing this for years. Without knowing a word in a foreign langauge one can tell by this number exactly what the article is about.

Otto W. Walther
Walther Electric Co.
Hughson, Calif.

Editor, I&CS:

To file select articles in a loose leaf file, and to have the widest option of articles saved, I can see the advantage gained in separating the articles with advertisements. I like to save the entire context of the magazine without having to store extraneous matter; I much prefer to have complete separation of the articles and the advertisements.

I have for some years saved only the articles plus the index of each issue and have been keeping them bound in reference book form. I tab each issue with vol. and month number and keep a subject index and have found this system compact and fairly easy to refer to. The addition of advertisements spoil the appearance of the copy and means that I have extra useless sheets to bind. So I would appreciate it very much if you will give considerable thought to this subject before you change your magazine's present good form for a different system.

Charles D. Myers
Goodyear Tire & Rubber Co.
Jackson, Michigan

We wish we could please everybody. Our mail, however, has been running heavily in favor of separating articles by advertisements.

Editor, I&CS:

We have, on occasion, the problem of arranging for climatic and altitude tests and although some of the test chambers installed in this country are

Now there's a New "Jeweled" Escapement in ROCKWELL CHART DRIVES

for greater accuracy and longer life

This jeweled movement brings fine watch quality to instrument timing

The introduction of a jeweled movement—the first ever used on a general industrial timing device made in the United States—makes the Rockwell more accurate than any unjeweled chart drive could possibly be. In addition to offering fine watch quality, the jeweled escapement requires less power to operate and is extremely durable, since seven hard jewel surfaces are provided to limit friction and wear.

You will benefit in many ways by using these jeweled movement chart drives for powering all your recording instruments. They adapt readily to fit into practically any instrument case while speed-changing turrets (see left) permit changing rotation rates at will. Write for full information. Rockwell Manufacturing Company, Instrument Division, Pittsburgh 8, Pa.

SPEED CHANGING TURRETS PROVIDE SEVEN DIFFERENT ROTATION RATES

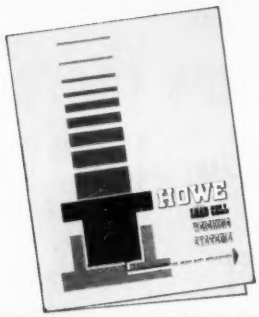
The basic Rockwell Chart Drive has a main arbor rotation rate of 7 days. Economical snap-on turrets permit changing to 8-day, 15-day, 16-day, 24-day, 30-day, 31-day, and 24-hour rotation. No tools or special skills are required. You can even change chart rotation without removing the drive from the instrument.

JEWELED CHART DRIVES

another fine product by

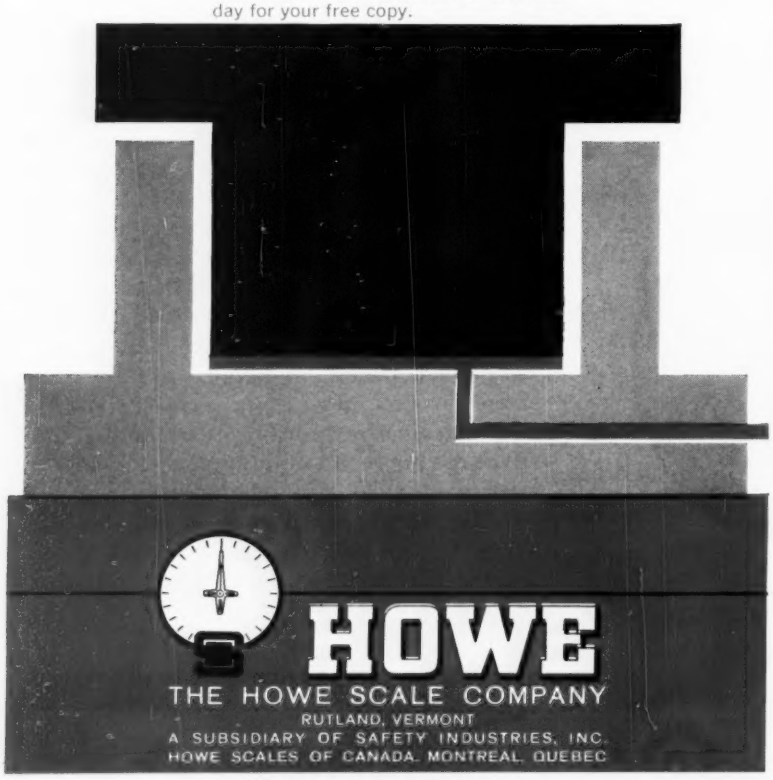
ROCKWELL

CIRCLE 7 ON READER-SERVICE CARD



NEW HOWE LOAD CELL WEIGHING SYSTEMS FOLDER

Here's complete information on the latest in load cell weighing systems for heavy duty installations—how it works, advantages, applications, components, instruments and accessories. Write today for your free copy.



CIRCLE 8 ON READER-SERVICE CARD

ICS LETTERS TO THE EDITOR

known to us, we are certain that there are many that we have not heard of. In order that we might have the opportunity of contacting the closest appropriate facility, we are wondering if there has been any survey made which has resulted in a listing of such facilities, together with nominal capabilities of these facilities.

G. F. Johnson
Manager, Experimental Laboratory
Joy Manufacturing Company
Michigan City, Indiana

Such a survey appeared in our July, 1958 issue and also in the October 1958 issue.

Editor, I&CS:

In your November issue "To the Editor" column, I note a reference to an article entitled "Slide Rules" and also to Mr. Hunt's article on "The Use of the Slide Rule."

If possible, I would appreciate receiving reprints of these two articles, since I have tried unsuccessfully to find which issue they appeared in.

A. L. Westburg
Seico Instrument Div.
Eclipse Fuel Eng. Co.
Rockford, Ill.

They were in the November, 1958 issue.

Editor, I&CS:

The article by Kaufman and Dress in the November issue contains an unfortunate section on "Calculated Tolerances".

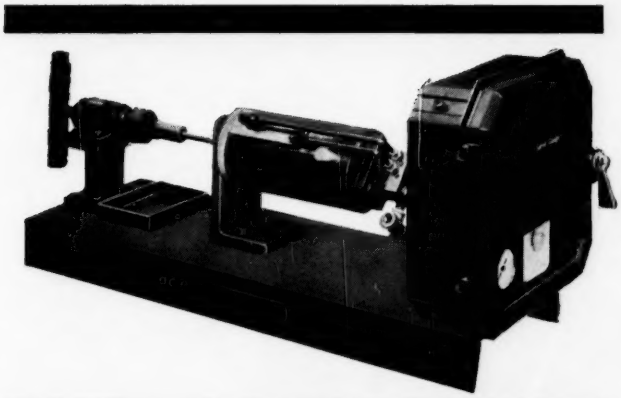
In the first place, a tolerance has no meaning unless it is associated with a probability. A statement should be made such as: "99.7% of readings on an instrument will be within $\pm 0.1\%$ of the correct value".

If all tolerances are additive, the resulting tolerance is the square root of the sum of the squares of the individual tolerance *expressed with the same probability.*

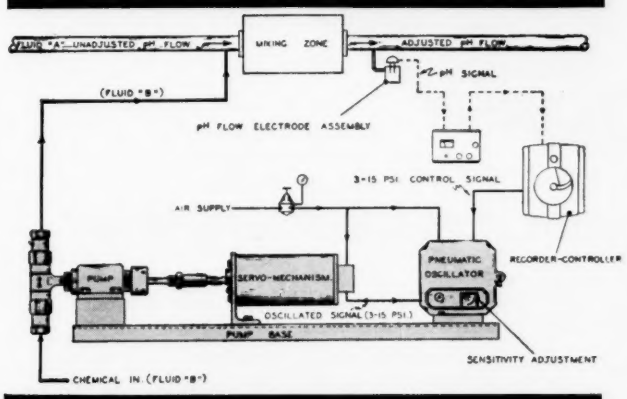
The probable error is an anachronism which should not be revived, and the formula given is wrong anyway. As long ago as 1928 the great statistician R. A. Fisher said, "the common use of the probable error is its only recommendation . . . when any critical test is required, the deviation must be expressed in terms of the standard error."*

Probable error has recently been

*Fisher, R. A. *Statistical Methods for Research Workers,* 1928, *p.* 46.



This new Servo-Gauge Metering Pump System, designed for all-pneumatic actuation and control, brings increased uniformity and quality to continuous processes because (1) the positive-displacement plunger positioning accuracy is within 0.002 inch, repeatedly; (2) there are no bearings or linkages to wear and introduce inaccuracies; and (3) the pump is fitted with dual check valves to prevent backflow.

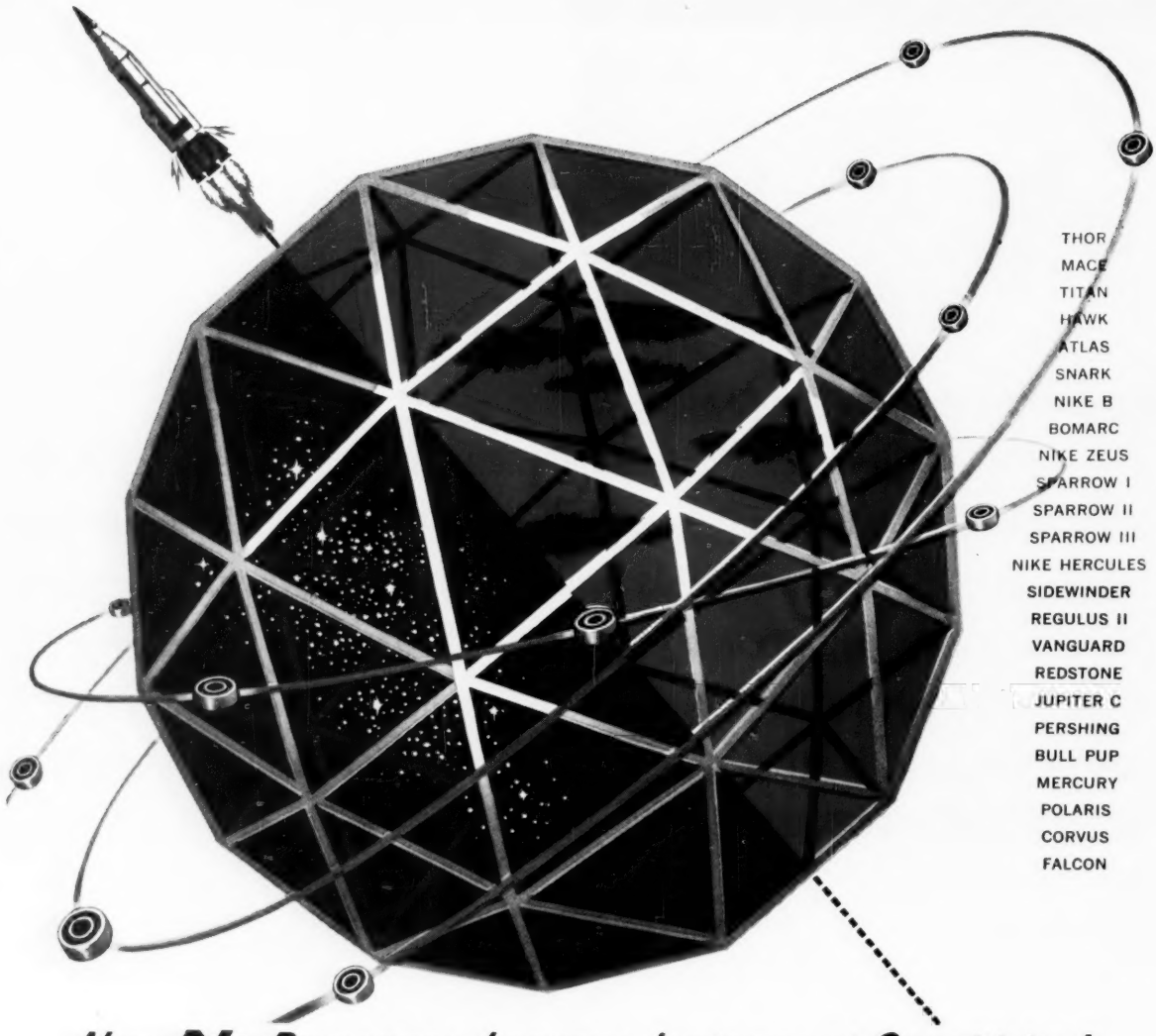


Accuracy of this proportioning pump is maintained under either steady or variable flow conditions. Here, for example, is a typical Process Variable Control Application (Flow diagram). A liquid **B** can be pumped at a variable rate into process line carrying fluid **A** by using output signal from a controller to adjust stroke length of pump. For example, pH adjustment can be obtained in this manner by controlling rate at which chemical **B** is pumped into fluid. Frequency setting adjusts sensitivity of system—at low oscillator cycle rate, controller output must be higher to give long stroke required to produce a given discharge rate of liquid **B**, hence permitting a wider variation in the measured variable for a given controller setting.

Principal features, typical applications, maintenance and installation economies are discussed in our bulletin P-21. Write for a copy. Address Associated Control Equipment, Inc., P.O. Box 136, Coraopolis, Pa.

A word about Associated Control Equipment, Inc.—This is a new company, engaged in the design, engineering, and manufacturing of specialized control equipment. The basic concept of our operations is the standardization of custom or modified control equipment.

CIRCLE 9 ON READER-SERVICE CARD



New ND Processes Improve Instrument Sensitivity!

In delicately-precise instrumentation, parts must react to relatively small rotive forces. Here . . . bearing torque is the highly critical factor. Separator selection, bearing finish and clinically clean assembly areas are extremely important.

It's here that New Departure is setting new industry standards! Special dies and in-process gauging of separators assure ball retention with improved torque and vibration characteristics. In addition, new N.D. honing processes and Talyrond gauging deliver uniform accuracy to millionths of an inch. Moreover, having originated the first bearing industry "white room", followed by continuous experience, New Departure's present day, modern assembly areas approach fantastic levels of cleanliness.

An everyday example of N.D.'s contribution to improved instrument sensitivity can be found in the Smithsonian Institution-selected Micro Clocks. These vitally important instruments are accurately tracking both U.S. and foreign satellite movements in time determinations of 1 milli-second . . . and better!

For new *performance* and *reliability* in your precision instruments, ask your N.D. Miniature/Instrument Bearing *Specialist* to sit in on early design level discussions. For further information call or write Department L.S., New Departure Division, General Motors Corp., Bristol, Conn.

NEW DEPARTURE

MINIATURE & INSTRUMENT BALL BEARINGS

proved reliability ***you can build around***

CIRCLE 14 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

used even less, and would not be called "common" today.

The problem of precision vs accuracy has been ignored. The ASTM has some excellent publications on this subject.

It is encouraging to see even a paragraph on tolerances or precision. The time is not far off when these terms will be generally understood and no paper will be complete without accurate statements of their magnitude.

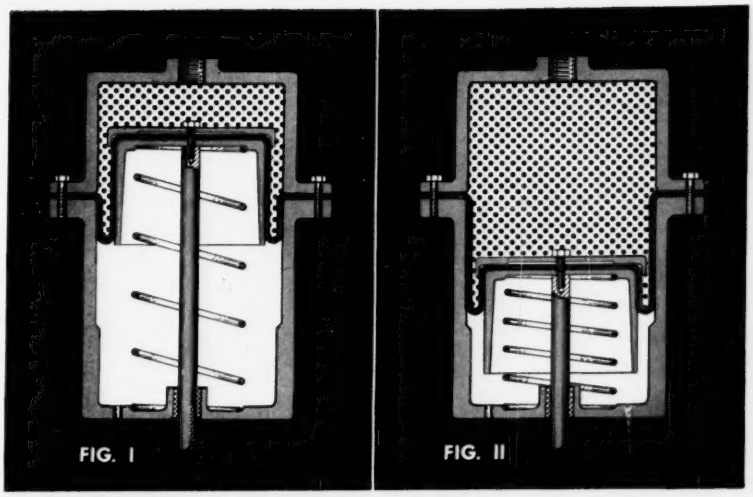
E. Harvey Barnett
Monsanto Chemical Co.
St. Louis 77, Mo.

The authors reply:

The authors have read Mr. Barnett's letter regarding a statistical analysis. Mr. Barnett has indicated that the equation used for probable error is incorrect and an anachonism. He stated that the words "probable error" should be "standard deviation" and that the equation presented should not have had the sum of the squares of the individual tolerances divided by said sum. Mr. Barnett is correct to some extent.

Unfortunately, there appears to be lack of communications between engineering fields, and a lack of understanding on the part of the statistical analyst on the application of his work to the electrical field. Standard deviation can only apply properly where there is sufficient statistical data to secure the standard deviation of a particular quantity from its mean. In this particular case standard deviation of a given measurement instrument at the hundreds of measurement points used is not easily obtainable. Therefore, the maximum error of each measurement deviation or equipment was utilized in the article equation to secure what was called *probable error*. Probably a better word to have been used in describing the tolerance would have been *estimated error* rather than *probability*.

It is agreed that the division of the individual squared and summed tolerances by the sum n should not have been employed. This would give standard deviation, and $\frac{2}{3}$rds of this value probable error (per text book). Division by n—1 for the small sample used would approximate the $\frac{2}{3}$ of standard deviation value = probable error. Unfortunately some books on statistical analysis indicate the use



For Hydraulic and Pneumatic Applications

Nothing rolls like a Bellofram® Rolling Diaphragm. It's frictionless!

The Bellofram Rolling Diaphragm provides ultrasensitive response in hydraulic or pneumatic devices where frictionless, long-stroke action in small-diameter configurations is required . . . and where flex life of millions of cycles is necessary.

These desiderata are achieved through the *rolling* action of a flexible thin-sidewall diaphragm consisting of a high-tenacity fabric overlay embedded in elastomeric material.

Fig. I shows how Bellofram Rolling Diaphragm conforms to the piston. Fig. II shows how, as the piston descends under pressure, the diaphragm *rolls* off the piston's sidewall and onto the cylinder's sidewall in a smooth, continuous, frictionless movement.

The Bellofram principle can be applied widely in actuators, pumps, instruments, seals, accumulators, fluid dampers, etc.

Which of these advantages are you looking for?

To the designer confronted with situations for which conventional bellows, O-rings, or cup packings are inadequate, Bellofram Rolling Diaphragm offers a constellation of advantages found in no other product:

1. Friction-free (low hysteresis).
2. No break-out friction effects.
3. Completely leakproof device.
4. Constant area in all piston positions.
5. Almost infinite flex life (millions of cycles).
6. Sensitivity to extremely small pressure changes.
7. No mechanical spring gradient.
8. Compatibility with practically all environmental gases or fluids.
9. Automatic de-icing action.
10. Free positioning with complete relaxation at any point in its stroke.
11. Does not require close machine finish tolerances on pistons and cylinders.
12. Freedom from abrasive wear.
13. One hundred stock sizes. Four mounting configurations. Special types and sizes designed to order.
14. Excellent temperature stability, from —85°F. to 550°F. (from —120°F. to 700°F. in some cases).

Wide range of working pressures: 1 in. H_2O to 500 psi (up to 1200 psi in some cases).

Effective pressure areas from .028 to 108 sq. in.

Cylinder bore diameters from .25 to 12 in.

Extended range of stroke (.01 to 12 in.).

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This is an advanced design embodying broad experience gained from earlier Ferranti tape reader models.

It employs new transistorized circuits and a photoelectric system of reading . . . offers the advantage of speedier input of data, compactness, light weight.

Many design features to meet practical requirements of the user. Power supply is self-contained.

Write for detailed information.

TAPE WIDTHS:
5, 6, 7 or 8 level, all types and colors.

SPEED:
Any speed up to 330 chars/sec, under external control.

ELECTRONICS:
All solid state, including solar cell reading head, signal amplifiers, logical circuits, control circuits and power supplies.

INPUTS:
115V 60 cps 115 Watts power, — 2 V 100 microamp start signal.

OUTPUTS:
8 signal outputs, — 1.5 to — 3.5 V 5 milliamps plus reader ready signal.

SIZE:
9¼" x 11½" x 10"
Weight 32 lbs.

FINISH:
Gray wrinkle.

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ELECTRONICS DIVISION
95 MADISON AVE., HEMPSTEAD, N.Y.

CIRCLE 11 ON READER-SERVICE CARD

ICS LETTERS TO THE EDITOR

of the standard deviation equation without the division by n; in other cases the division by n or $n-1$, depending on the quantity of statistical data secured, is used. The authors apparently misinterpreted where and when these three variations of the equation should be utilized. Therefore, the probable error data in table 3 is too low in value.

The authors wish to point out that standard deviation of each instrument for each measurement point was not secured and an attempt was made to find the estimated error of all instruments combined, utilizing the standard deviation equation and assuming that the instrument errors were randomly plus or minus. Additionally, it should be noted that standard deviation indicates a value (the extent of deviation from a mean) and that this mean is not the variation from an absolute measured quantity (in this case at least). Therefore, a deviation of, for example 5°F does not mean a deviation of 5°F from the absolute quantity which it is desired to measure. In other fields it is possible to secure a family of statistical data and compute a mean deviation from the absolute value; in the instrumentation field this may be impractical unless access to primary standards is available from which the deviation data can be secured. In statistical books the standard deviation subject, for example, was the variation of mean height of 8 year old children, which can be secured readily by a ruler; not so in the instrumentation field.

The authors believe that this is a fruitful field for further exploration by a statistician who is concerned with instrumentation measurement. Quality control, biomeasurements, etc., do not fall in the same category (where deviation from a mean value is acceptable). In instrumentation, variation from an absolute value is required.

Alvin B. Kaufman

Editor, I&CS:

I wish to thank you for your help in locating a suitable EMF to pressure tranducer . . . (several companies) have units which will meet my needs. Their companies contacted me through your efforts.

S. B. Walton
San Jose State College
San Jose, Calif.

• Inserts match thermocouple alloy
• Inserts easily interchangeable
• Color coded discs for easy calibration identification
• Number discs for easy identification of individual T/C's

NEW

*QuiK-Konnect** thermocouple components

For accurate, swift, and foolproof connection of thermocouples to extension wire

New *QuiK-Konnect* plug and jack bodies give fast, easy, and foolproof extension wire connections in plant, laboratory or test cell installations.

Inserts have different diameter positive and negative poles, for foolproof connection . . . are extremely easy to remove for field calibration change or replacement. Various tube adapters are available to protect small-diameter thermocouples, and cable clamps can be supplied to protect extension wires from fraying or tearing.

The *QuiK-Konnect* line, in addition to plugs and jacks, includes:

1. Single-jack panel that fits ¾-in. knockout.
2. 4-point jack panel that fits standard electrical outlet box.
3. Multiple jack strips.
4. Custom-built multiple jack panels.
5. *QuiK-Kords** for patch programming multiple jack panels.

You can get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, 21 Penn St., Fall River, Mass.

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75th YEAR PIONEERING THE FUTURE

Honeywell

First in Control

SINCE 1885

CIRCLE 10 ON READER-SERVICE CARD

Tubexperience in action

Bellows courtesy Clifford Manufacturing Company, Boston, Mass.

750,000 flexures without failure

—a common performance record for bellows formed from Superior Thin-Wall Tubing

Bellows, more sensitive than spirals and better adapted to accurate measurement of pressure and vacuum, or absolute pressure in the low and intermediate range, must withstand thousands of flexures without failure. The tubing from which they are made must be highly uniform in physical and mechanical properties and must have the invariably smooth surfaces that contribute so much to good fatigue life. It must be extremely ductile—forming pressures run as high as 5000 psi. Brazing operations used to fasten it to another assembly may subject it to temperatures up to 1800°F. It must have excellent corrosion resistant characteristics. And it must be free of carburization, dents and pickups that lead to premature fatigue failure of the bellows in service.

Thin-wall tubing of this quality—usually under .010 in. max. wall thickness and held to a tolerance spread of only one-thousandth inch—requires the skills and facilities of tubing specialists. Superior maintains production standards fully in keeping, employs special handling procedures, uses special controlled-atmosphere furnaces to provide the uniformly annealed tubing demanded. Superior tubing is produced in a wide range of analyses, in both Seamless and WELDRAWN® types, and to specified IDs, ODs and wall thicknesses.

Bellows tubing is just one of many types supplied by Superior. Available are more than 120 analyses, in a wide range of sizes, and meeting almost any requirement. For a good glimpse of the field covered by Superior, send for Bulletin 41. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 13 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

Editor, I&CS:

Regarding the article "630 Watt D. C. to D. C. Converter," published under "Electronic Circuitry" in the November issue of *INSTRUMENTS AND CONTROL SYSTEMS*, perhaps the line which reads "wire size must be large enough to allow one circular mil per ampere" should be revised before some hapless person decides to take you at your word.

"1000 circular mils per ampere" might be more practical.

W. T. Hage,
The Babcock & Wilcox Co.
Alliance, Ohio

It should be "1 circular mil per milliampere." Sorry.

Editor, I&CS:

Your help is requested in answering a question which has arisen in our Electronics Department concerning the effect of mercury vapor on selenium rectifiers.

Is it true that mercury, even in minute quantities, poisons selenium rectifiers? If such is the case, what concentrations of mercury vapor adversely affect these rectifiers?

B. T. Wood
Masonite Corp.
Laurel, Mississippi

International Rectifier Corporation answers this question as follows:

Our investigations have shown that mercury vapor will affect the selenium rectifiers by causing the reverse resistance to become much lower. If the rectifier is operating while this occurs, the rectifier will heat up and melt due to the increased reverse current. Our investigations did not include degrees of concentration of mercury vapor necessary for this effect.

If additional information is required, we suggest you contact the Battelle Memorial Institute and the University of Pennsylvania, both of which have performed extensive tests under Government Contracts on this subject.

We wish to point out that not in all cases will the presence of small amounts of mercury vapor cause adverse effects on selenium rectifiers. From our experience we feel that in the majority of cases, small amounts of mercury vapor will not affect the operation of the selenium rectifiers. However, if large amounts of mercury vapor are present due

Statham
Deep in the heart of nearly every ballistic missile in the nation's space-age arsenal is the Statham transducer. Of more than 40,000 parts in a missile, none is more vital than its transducing elements. Without them, it would be difficult if not impossible to determine component reliability or to record the functional performance of the missile in space.
Typical of these rugged instruments is Statham's new 250-millivolt high output pressure transducer that permits direct connection or commutation to low level voltage-controlled oscillators. This X-volt series, designed for sophisticated instrumentation, is fully described in Data File ICS-909-2.
For leadership in measurement
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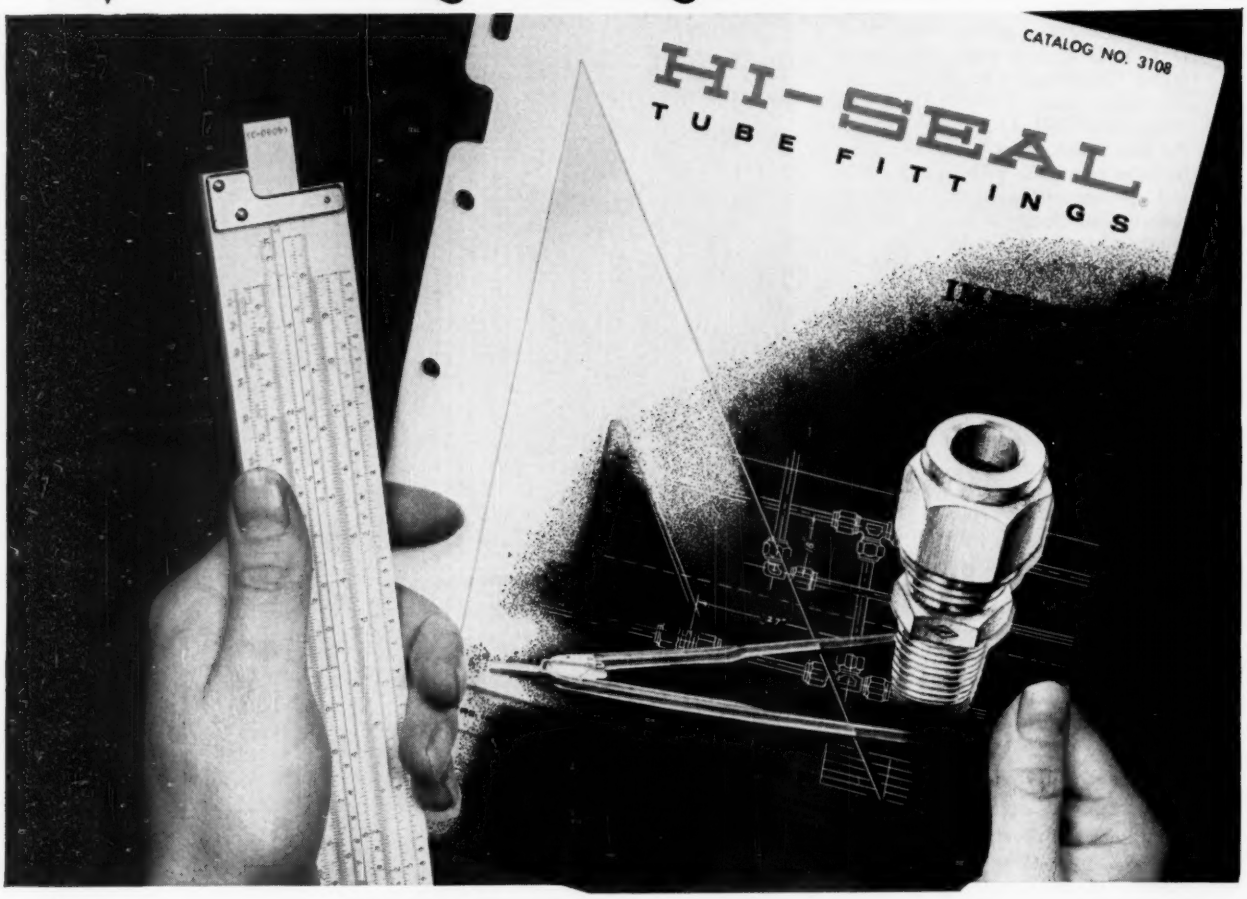


Your slide rule or this New Hi-Seal Tube Fitting Catalog...

YOU'LL WONDER WHICH ONE HELPS YOU MOST!

Just off the press! A working handbook for every man concerned with tubing and fitting circuitry. Published by the company with a habit of leadership.

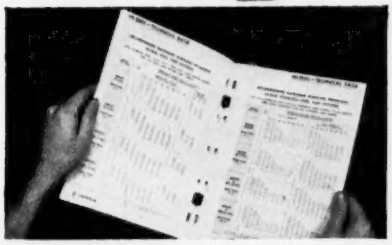
Leading hydraulic and pneumatic engineers, when asked to study advance proof copies of Imperial's new Hi-Seal Catalog, came back with comments like these: "It's a reference manual" . . . "The kind of material I've had to dig up for myself, until now, from several reference sources" . . . "Make sure I'm on your list for a copy as soon as they are available."

The new Imperial Catalog of Hi-Seal tube fittings contains data, charts, laboratory tests, and formulae on corrosion, vibration, temperature, pressure and vacuum, flow and velocity — vital statistics in hydraulic and pneumatic tubing circuitry design. And it describes the complete line of Imperial Hi-Seal Tube Fittings — *industry's most complete line*, based on a single-design concept, that meets all tubing circuitry requirements. All items in this catalog are stock items and are priced as stock items.

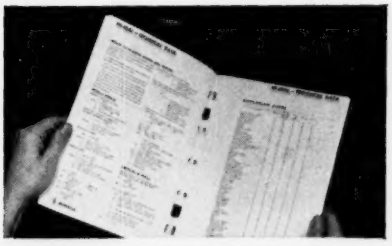
THE IMPERIAL BRASS MANUFACTURING CO.
Dept. ICS-20, 6300 West Howard Street, Chicago 48, Ill.
In Canada: 18 Hook Avenue, Toronto, Ontario

CIRCLE 15 ON READER-SERVICE CARD

How Imperial's new Hi-Seal Catalog helps you solve these problems:

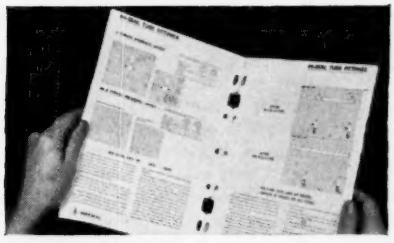


SUPER-HIGH PRESSURES. At your fingertips: five pages of recommended maximum working pressures for a variety of tubing materials, from minor to 150% surge with a safety factor of ten, including Braze-Seal Fittings, the first and only make and break joint for extreme pressures and temperatures.



CORROSIVE ATMOSPHERES. Engineering Data: Comprehensive chart rates 140 fluids — from sour gasoline to oxalic acid — and the effect each has on six stainless alloys, brass, copper and aluminum.

Also covered: formulae for calculating surge pressures, tube bursting pressures, Saybolt viscosity, Reynolds number, Harris formula, and others.



SPACE LIMITATIONS. Pages of facts, diagrams, sample systems, showing how Hi-Seal's unique design concept — throughout the complete line — can produce layouts that are more compact, save space, save time, save tubing.

Get your copy of the new Imperial Hi-Seal Tube Fitting Catalog now. Tell us which type of fitting you are most interested in — we'll send you a free sample.

CIRCLE 15 ON READER-SERVICE CARD

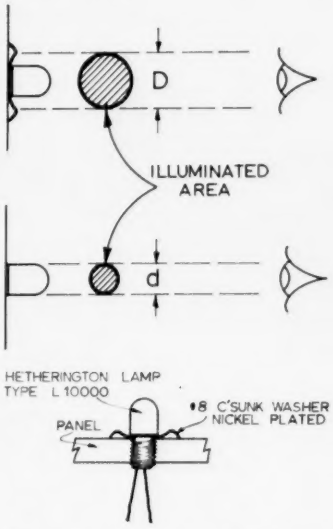
I&CS LETTERS TO THE EDITOR

to the switching of mercury switches or in process involving the use of mercury where vapors are given off, that it may be advisable to hermetically seal the selenium rectifiers.

Glenn Geissinger,
International Rectifier Corp.,
El Segundo, Calif.

Editor, I&CS:

New indicator lamps are now available which have very simple (threaded hole) mounting and exceptionally long life. They are very desirable for use on multi-indicator panels. However, these lamps are considerably smaller than the ½" diameter commonly used before, consequently have lower visibility.



We found that the visibility of these smaller lamps on our indicator panels could be made equal to that of the larger lamps previously used by this simple inexpensive expedient. Place a size 8 countersunk nickel plated washer so it is held firmly against the panel by the lamp holder. This increases the illuminated area (when the light goes on) from the circle of small diameter d to one of the larger diameter D.

Charles Pass,
Electronics Engineering Dept.
Lawrence Radiation Laboratory
Livermore, Calif.

Editor, I&CS:

Regarding Major M. F. Behar's perference for "sinoidal" instead of "sinusoidal", I should like to refer you to page 129 of *Makers of Mathematics*, by Alfred Hooper (Modern Library Paperbacks, 1948), where the author points out the etymological derivation of "sine" from the Latin word "sinus."

This unmathematical Latin comes from a translator's error some 800 years ago.

Gerald S. Gordon
Minneapolis-Honeywell
Boston, Mass.

READER INQUIRIES

Rubber Hardness Tester

Export company seeks rubber hardness testers with a scale of 0 to 380 shores. A-608

Underground Water Detector

Vice president of sales for importing company seeks supplier of electronic underground water detectors to be used in desert at great depth. A-607

Card Punching Unit

Consulting engineer seeks card-punching component which can be designed into mechanical computer for direct transfer of several categories of totals to approximately 30 columns of 80-column IBM-type card. May be slow-speed unit as card insertions will be less than 12 in 24 hours. Must withstand shock, vibration, and temperature ranges encountered in rail and bus transportation systems. A-606

Plastic Pressure Taps

Owner of instrument company seeks hard-rubber or Teflon "sandwiches" with pressure taps to fit between welding-neck flanges for phosphoric acid flow service. A-605

Portable Recording Frequency Meter

Electronics wholesale distributor seeks portable recording a-c frequency meter with 6" chart minimum and chart speed 3" hr. Input voltage will be controlled to any desired level from 70 to 250 v at any frequency which should be selectable by internal range changing device from 25-30; 30-35; 35-40;40-45; 45-50; 50-55; 55-60; 60-65 cps. Desired: accuracy—0.1% or better; response—0.7 sec or better. Other ranges are acceptable, if approximately 5 cycles cover width of chart. External means of range selection acceptable, if more practical. A-604

MARKET PLACE

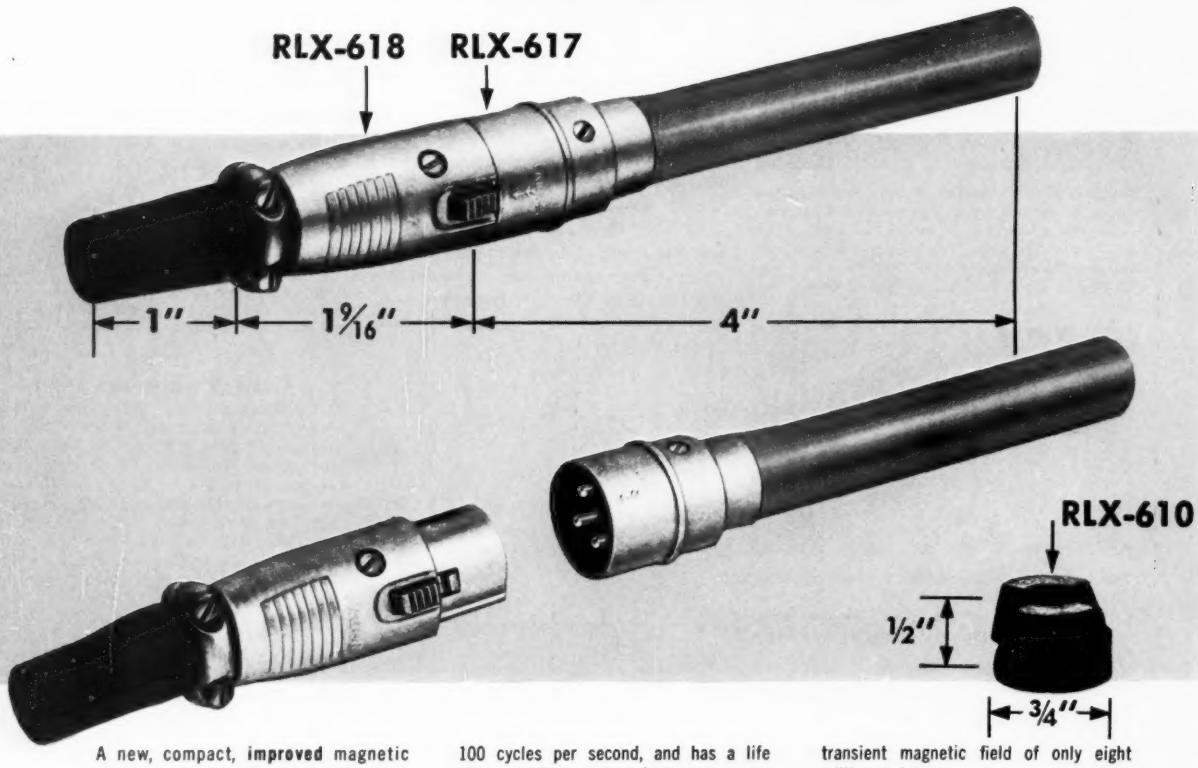
Electronic Instruments Line Available

Established manufacturer of electronic instruments going into manufacture of computer components and systems engineering wishes to sell instruments line which includes power amplifiers, semiconductor testers, CR indicators, pulsers, frequency oscillators, etc. Write to Market Place, c/o Instruments Publishing Company, 845 Ridge Ave., Pittsburg 12, Pa.

MODEL MH-2-P

NEW . . . IMPROVED

MAGNETIC SWITCH



A new, compact, **improved** magnetic switch . . . neatly contained in an epoxy resin shell. The Post MH-2-P, is a magnetically operated sensing device for industrial applications. This proven product may be used to actuate electronic or mechanical counters, controls, solenoids, relays or other types of circuits. The MH-2-P is easier to mount in areas of limited access, and features a quick disconnect Cannon connector.

The MH-2-P is capable of speeds up to 100 cycles per second, and has a life of many billion cycles. Contacts are single-pole, double-throw, rated at 5 amps. non-inductive.

The switch is operated by the proximity of a magnetic field which is usually provided by an Alnico magnet. When the magnet is moved close to the face of the switch, the switch arm transfers contact; and as the magnet moves away, the switch arm returns. Thus it is possible to operate from zero speed up to a transient magnetic field of only eight milliseconds.

By mounting a magnet on a rotating shaft or wheel, the MH-2-P is ideal for counting revolutions, synchronizing, or timing. The outstanding feature of this switch is its ability to provide a sharp, clean "make and break" with no bounce. This is important because the bounce in all other contactors will cause several counts for each contact closure in high speed electronic counters.

SPECIFICATIONS

SWITCH — Magnetic, hermetically sealed in a high-pressure hydrogen atmosphere in a glass capsule.
MOUNTING — Upright, within 45° from vertical.
CONTACTS — S.P.D.T. 5 amps. non-inductive (Mercury wetted contacts).
SPEED — Zero to 100 per second.
MINIMUM MAGNETIC FIELD TRANSIENT TIME — .008 seconds (8 milliseconds).
LIFE — Conservatively rated in excess of one billion operations.
WEIGHT — App. 3 ozs. **OVERALL HEIGHT** — 5⅝ in.
ENCLOSURE — Epoxy Resin. **COLOR** — Grey
MAXIMUM AMBIENT TEMPERATURE — 100°F (Consult factory if switch is to be operated at higher temps.)

The usual contact "bounce" is eliminated by virtue of the damping action of a capillary film of mercury.

Decitron

ELECTRONIC PRODUCTS DIVISION

POST MACHINERY COMPANY

175 Eliot Street, Beverly, Massachusetts

CIRCLE 16 ON READER-SERVICE CARD

Power-supply market is reported by Technical Information Corporation as follows:

LABORATORY TYPE (Below 1000 V and 3A)	1957	1958	1959
Number of Manufacturers	36	48	65
Number of Instruments	333	432	564
Price Range, Minimum	$ 35	$ 35	$ 35
Maximum	$2470	$2470	$2470
Average Price	$ 426	$ 443	$ 410
Median Price	$ 340	$ 375	$ 335

HIGH CURRENT TYPE (Above 3 Amps)	1957	1958	1959
Number of Instruments	17	26	33
Number of Manufacturers	146	190	315
Price Range, Minimum	$ 40	$ 32	$ 32
Maximum	$1285	$1480	$2300
Average Price	$ 462	$ 500	$ 635
Median Price	$ 410	$ 525	$ 595

% CHANGE FROM '57 to '59	LAB TYPE	HIGH CURRENT TYPE
Manufacturers	Up 80.5%	Up 94.2%
Instruments	Up 69.1%	Up 115.8%
Average Price	Down 3.8%	Up 37.4%

BDSA, Dept. of Commerce, reports electronics output from 1947-1960 as follows (in millions of dollars):

Year	Home-type radio and television receivers, and related products	All other electronic equipment 2/	Electron tubes	Semi-conductor devices	Electronic components other than tubes and semiconductors
1960	2,200 e	4,650 e	930 e	470 e	1,800 e
1959	1,950 p	4,000 p	880 p	370 p	1,600 p
1958	1,350	3,250	790	210	1,340
1957	1,500	3,100	820	150	1,450
1956	1,470	2,800	790	90	1,360
1955	1,500	2,500	770	40	1,360
1954	1,420	2,470	690	25	1,275
1953	1,593	2,503	734	25	1,445
1952	1,340	2,330	690	20	1,110
1951	1,296	843	473	3/	788
1950	1,687	473	443		697
1947	810	469	122		349

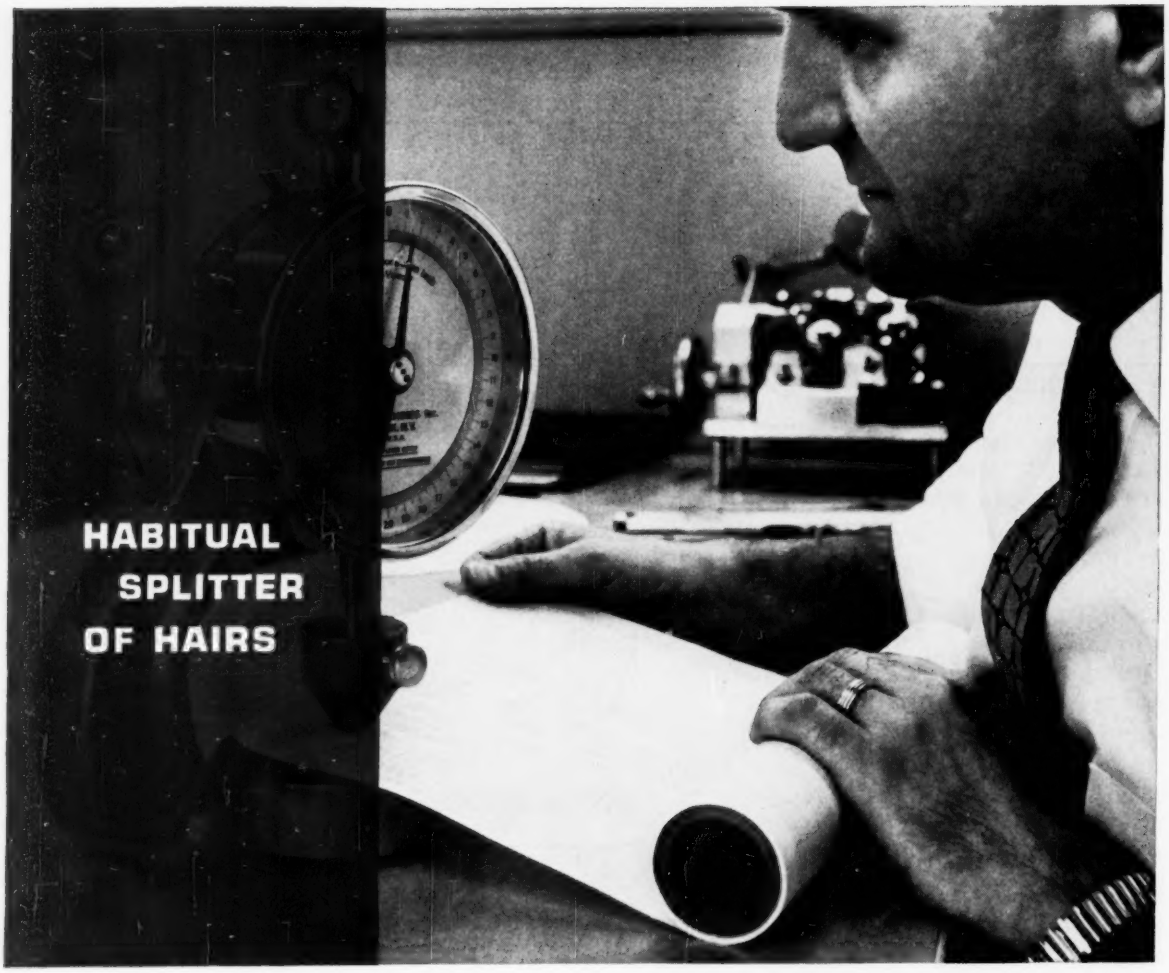
e—Estimated
p—Preliminary

1/ Data cover manufacturers' shipments. The totals represent the factory value of production or shipments (output) of electronic products, whether incorporated in other products or used in maintenance and repair of end equipment.

2/ Does not include payments on research and development contracts.

3/ Data for years prior to 1952 are included in "Electronic components other than tubes and semiconductors."

Sources: Census of Manufactures; the Annual Survey of Manufactures; releases of the Electronic Industries Association Marketing Data Department; BDSA surveys; and other sources.



. . . *because a mil can matter greatly in* RECORDING CHART PERFORMANCE

Even a fraction of a mil can bulk large in the thickness of a recording chart. That's why John Mazurowski and his thickness micrometer are so important to chart users.

A process change in an eastern oil refinery, for example, called for a longer strip chart in a temperature recorder — but the diameter of the roll could be no bigger than before. GC engineers solved this problem by working with our paper mills to reduce chart paper thickness from 0.00275" to 0.0019" while preserving strength and flexibility.

To make sure our charts meet the requirements of your instruments, GC engineers test paper stock for moisture content and tear-strength, too. This rigid inspection of paper that is produced exactly to GC specifications is a major reason why GC Recording Charts consistently fulfill their promise of accurate performance.

Other reasons for GC quality include our special formula printing inks, our exclusive innovations in plate-making and printing, and the scrupulous humidity control maintained throughout our manufacturing and storage areas.

GC Recording Charts have become standard equipment in more than 5,000 plants today. We stock more than 15,000 different charts—and will design and produce accurate special-purpose charts. Send for our 1960 Stock List — and for sample charts.

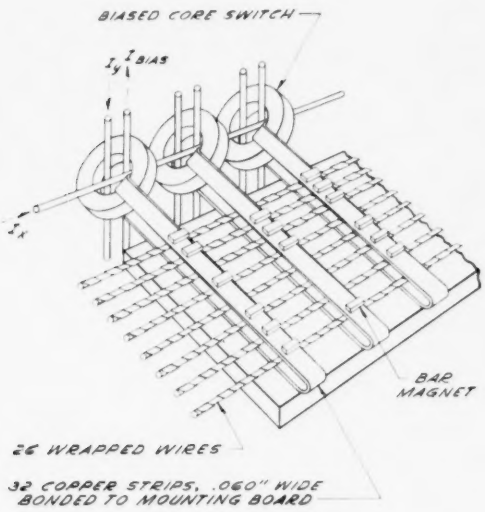
RECORDING CHARTS

CIRCLE 17 ON READER-SERVICE CARD

Twistor Permanent-Magnet Memory Now Mass-Produced

NEW YORK, N. Y.—Bell Labs and Western Electric have joined forces to mass-produce a new, accurate and fast electronic memory which will supply bits of information at speeds in millionths of a second to a computer.

Development of this efficient, comparatively inexpensive memory was reported by *I&CS* more than a year ago. Now, manufacture of the memory modules in quantity has been accomplished.



The memory module is built up of arrays of tiny permanent bar magnets located on plastic cards which are superimposed on a Twistor-conductor grid sensing element. The magnetic material, Vicalloy I is bonded in a 0.001"-thick sheet to a plastic card then subjected to a photoetching process to leave small bars at specifically desired locations. The sensing element for these magnets is an underlying grid of horizontal and vertical conductors. The wires running in one direction are magnetic and are called Twistors, while those running in the perpendicular direction are current conductors. A spiral wrapping of molypermalloy magnetic tape around a copper carrier wire forms a Twistor. The finished card—not unlike a punched card—is used to store information and give commands to the computer. The Magnet-Twistor memory transmits an electric pulse if there is no magnet at a specific location of the card, or is blocked if there is a magnet present.

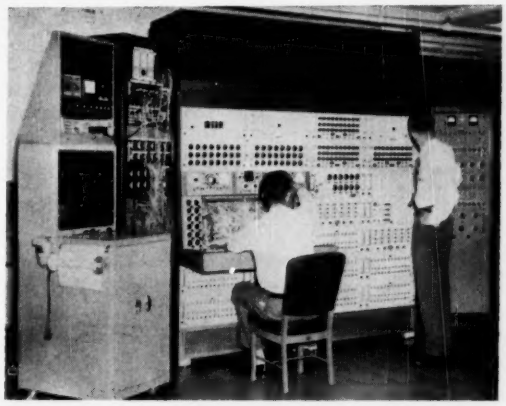
By inserting a new card with a different arrangement of magnets, the memory can be changed easily to a new program.

BENDIX AVIATION's G-15 digital computer is being tested at the U. S. Patent Office for streamlined patent searching by a serial scanning technique, and officials say it may accomplish in about half an hour a job that formerly took a skilled researcher up to a full day. The agency's punched-card file, which heretofore could be processed only on specially-built equipment, has been adapted to commercially available data-processing equipment.

I&CS NEWS

Analog Computer Tests Nuclear Control System Ahead of Start-Up

CLEVELAND, OHIO.—Engineers in the Analytical Div. of the Bailey Meter Company's Research Dept. (1050 Ivanhoe Rd., Cleveland 10, Ohio) use process simulation techniques and equipment to study operation of the Enrico Fermi Atomic Power Plant, well in advance of actual start-up.



Bailey Meter, prime instrument and control contractor for the Fermi plant, manufactured the reactor operating controls, the steam pressure control, the feedwater-valves and pump control, and the complete panels.

Simulation involved programming a Goodyear EDA to simulate the fast-breeder nuclear reactor, three intermediate heat exchangers, three once-through steam generators, and associated coolant piping loops.

FOR THIS LITERATURE CIRCLE 160 ON READER-SERVICE CARD

Dutch Export Capital Goods

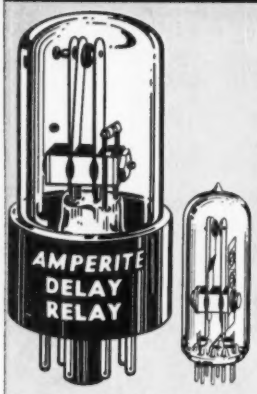
NEW YORK, N. Y.—The Netherlands, traditionally a land of dikes and tulips, are investigating exports of capital goods, including equipment for the chemical industries, to many nations.

A recent survey of fifteen of the largest chemical machinery producers in Holland revealed that all of these companies are interested in entering the American market. Some of the equipment producers are already represented here. In addition, eleven firms indicated interest in manufacturing American-patented equipment under licensing agreements for sale in the Netherlands and Euromart countries. Most of them would like to negotiate to have their products made in the United States.

Construction by a Dutch firm of a complete oil refinery in Ireland illustrates one type of apparatus already supplied by the Netherlands. The Netherlands (which houses the largest oil refinery on the continent of Europe) also supplies complete distilling units, fractionating columns and pipe lines with pumps, fittings, valves, etc.

AMPERITE

THERMOSTATIC
DELAY RELAYS



2 to 180 Seconds

Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.

Hermetically sealed. Not affected by altitude, moisture, or climate changes.

SPST only—normally open or closed.

Compensated for ambient temperature changes from —55° to +70° C. Heaters consume approximately 2 W. and may be operated continuously. The units are **rugged, explosion-proof, long-lived, and—inexpensive!**

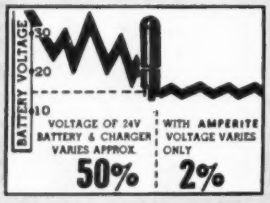
TYPES: Standard Radio Octal, and 9-Pin Miniature . . **List Price, $4.00.** Standard Delays

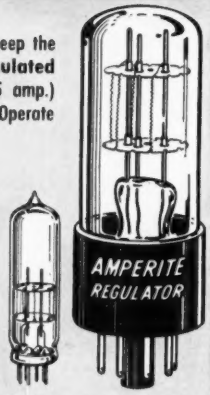
Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

AMPERITE
BALLAST REGULATORS

Amperite Regulators are designed to keep the current in a circuit **automatically regulated** at a definite value (for example, 0.5 amp.) . . . For currents of 60 ma. to 5 amps. Operate on A.C., D.C., or Pulsating Current.





Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—55° to +90° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE

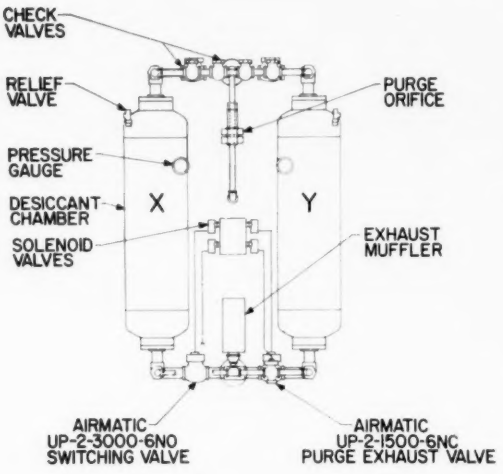
561 Broadway, New York 12, N. Y. . . . CAnal 6-1446
In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

RELAYS CIRCLE 19 ON READER-SERVICE CARD
REGULATORS CIRCLE 19 ON READER-SERVICE CARD

ICS **NEWS**

Instrument Air at Mobil Oil

BEAUMONT, TEXAS.—Instrument air in refineries must be free of moisture. A new dehumidifier (Heat-Les dryer, made by Trinity Equipment Corp., Cortland, N. Y.) at Mobil Oil Co.'s refinery near Beaumont, Texas, is making substantial savings in labor while at the same time piling up an enviable maintenance record. The dryer operates 24 hours a day, 7 days a week. In nine months time only one part, a check valve, has needed replacement. The heat-less dryer switches every minute



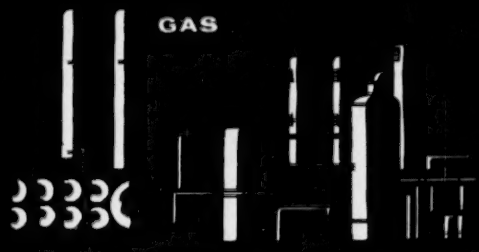
automatically and requires none of the operator's time. The desiccant is dried by using a small portion of the low-dew point air from the "operating" side. At the end of the operating cycle the chambers are automatically switched, allowing the reactivated chamber to dry the gas while other chamber is reactivated.

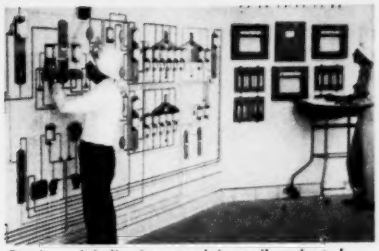
Because the wet air is switched from one chamber to the other every minute, it is important that the switching valves offer utmost reliability. For this important application Trinity Equipment selected the UP-2-3000-6NO valve made by Airmatic Valve, Inc., Cleveland, Ohio. The system is used to supply air to about 10,000 instruments in various parts of the refinery. The amount of purge gas required to activate the heat-less dryer is about 20% of the inlet flow. However, the cost of the purge air is considerably less than the comparable cost of the heat energy and purge air requirements of a heated-regenerated dryer.

TRINITY DEHUMIDIFIER CIRCLE 161 ON READER-SERVICE CARD
AIRMATIC VALVE CIRCLE 162 ON READER-SERVICE CARD

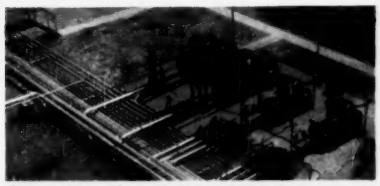
B. F. GOODRICH CHEMICAL CO. announces installation and operation of the "first computer control system in the chemical processing industry," based on a RW-300, manufactured by Thompson-Ramo-Wooldridge Products Company.

MONSANTO CHEMICAL CO. announces that the "first computer-controlled chemical plant" in the U. S. has begun start-up operation in Luling, La. System uses a RW-300.

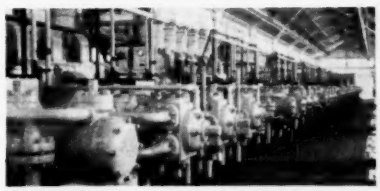




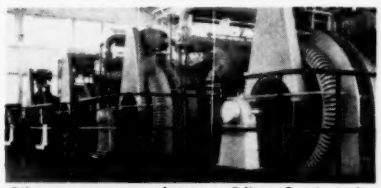
Omniguard indicating panel is easily adapted to miniaturized instrument panel installations for central control.



Detectors provide continuous temperature monitoring of drive motors for shipping pumps.



Omniguard system protects this bank of compressors installed at a natural gas cycling plant.



Oil company power plant uses Edison Omniguard system to protect generating equipment from overheating.

THOMAS A.

EDISON

omniguard system provides reliable, flexible temperature monitoring for oil, gas and petrochemical industries

Throughout your process, wherever temperature is critical, the Edison Omniguard system can protect vital equipment and output quality. It is the simplest and most flexible temperature monitoring system devised.

Plug-in detector units may be installed at key points throughout the process. They can be added or switched without disturbing the system. Typical detector locations include motor and motor bearings in shipping pumps, compressors and generating stations. Individual alarm settings on each point can be changed at any time without special tools.

Indicating panel can be located in central control room, for complete overall process monitoring by a single individual. Alarm system positively identifies trouble point.

The complete system is designed for utmost reliability. There are no moving parts, nothing to wear out.

Edison engineers will be happy to provide assistance in designing the most efficient system to meet your requirements.

For additional information write for publication 3036-C.

Thomas A. Edison Industries
INSTRUMENT DIVISION
24 LAKESIDE AVENUE, WEST ORANGE, N. J.

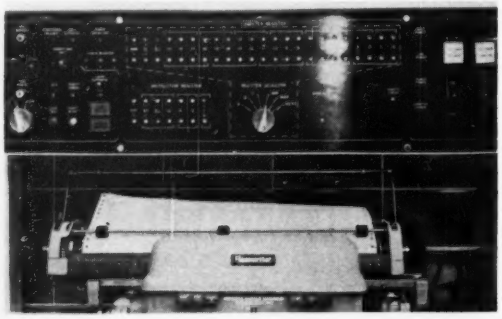
EDISON ENGINEERING OFFICES ARE LOCATED IN: CHICAGO; DALLAS; DAYTON; LOS ANGELES

CIRCLE 20 ON READER-SERVICE CARD

ICS NEWS

Computer Reliability Sets Record

NEW YORK, N. Y.—Reliability of a degree heretofore unknown in industry has been achieved during a six-month test run, just ended, by an electronic computer



system, installed by Daystrom, Incorporated at the Sterlington plant of the Louisiana Power and Light Company near Monroe (La.).

Over the six-month period, the system—made up of data logging and computer computational facilities—ran 99.75% of the time, 24 hours a day, 7 days a week, week in and week out, without stopping either for service or maintenance.

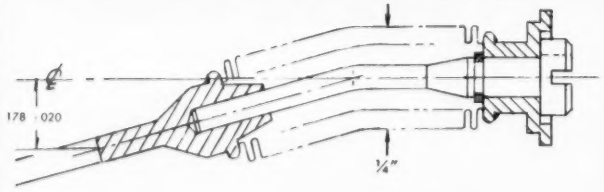
Microbiological Assay

WASHINGTON, D. C.—A new high-speed system utilizing an electronic computer to calculate laboratory data in six minutes, which previously required 30 hours of work by technicians, is now in use in the biological control laboratories of Chas. Pfizer & Co., Inc. The system, developed by Pfizer personnel, uses electronic equipment developed by International Business Machines Corp. of 590 Madison Ave., New York 22, N. Y. (IBM 650 computer and IBM 9600 console).

The arrangement is used in turbidimetric assays, tests which determine the potency of antibiotics and other drugs, based on the fact that bacteria grown in test-tube

SEALED ADJUSTOR

MAINTAIN VACUUM WHILE ADJUSTING HERMETICALLY SEALED UNITS WITH ROBERTSHAW ADJUSTOR ASSEMBLY

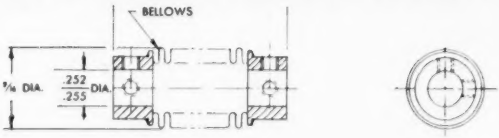


Now . . . adjust or recalibrate hermetically sealed instruments without breaking the vacuum. Robertshaw Adjustor Assemblies permit 360° adjustment. Heat treated steel shaft inside miniature seamless metallic bellows transmits torque from external source to internal mechanism. Leak tested on mass spectrometer. Unit shown is a zero adjustor for an aircraft instrument. Available as custom units with bellows as small as ¼" O.D. WRITE FOR ENGINEERING DATA SHEET F102!

CIRCLE 21 ON READER-SERVICE CARD

FLEXIBLE COUPLING

ELIMINATE BACKLASH, END-PLAY! ABSORB VIBRATION, SHOCK WITH ROBERTSHAW FLEXIBLE COUPLINGS



Servomechanisms, instruments and similar drive and control systems are the big users of these small, flexible units. Ideal for guarding against misalignment friction and bearing wear problems. Save space and weight. Cut down noise. Simplified design utilizes seamless metallic bellows, in choice of several metals, connected to two hubs. Sizes from 15/32" O.D. Stock sizes accommodate shafts from ⅛" to ½". Other sizes custom-engineered. WRITE FOR DATA SHEET F802!

CIRCLE 22 ON READER-SERVICE CARD

solutions cause cloudiness, or turbidity. Adding an antibiotic to the test tube inhibits the growth of the bacteria, reduces the turbidity and thus causes the solution to appear more transparent. The degree of turbidity, indicating the potency of the antibiotic, is measured by a spectrophotometer made by Bausch & Lomb (738 St. Paul St., Rochester 2, N. Y.). A digital voltmeter (manufactured by Non-Linear Systems, Inc., Del Mar Airport, Del Mar, Calif.), which converts voltage output of the spectrophotometer to digital pulses, rounds out the equipment.

FOR SPECTROPHOTOMETER CIRCLE 163 ON READER-SERVICE CARD
FOR DIGITAL VOLTMETER CIRCLE 164 ON READER-SERVICE CARD

WESCON, whose show is scheduled for August 23-26, 1960, has set the deadline for papers by May 1. They should be sent to Richard G. Leitner, Chm. of the Technical Program. WESCON Business Office, 1435 South La Cienega Blvd., Los Angeles 35, Calif.

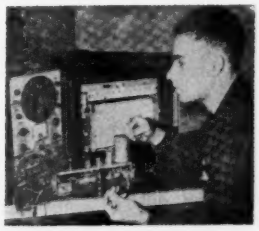
WESTERN RESERVE UNIVERSITY has received a grant of $129,900 from the National Science Foundation for conducting a summer institute for high-school teachers of science and mathematics. No fees will be charged. Applications must be postmarked on or before February 15, 1960.

N/P COMPANY, Box 127, Temple City, Calif. offers new nameplate service—preparing suitable legends (from flow sheets, electrical schematics, plant surveys), recommending methods of mounting, and materials, and actual installation.

A. KEGEL of Westinghouse has proposed that control systems be classified in terms of the slopes of the asymptotes of the loop-gain vs. frequency curve on log-log paper (rather than present two-position, proportional, floating and rate classifications).

DU MONT has installed an ITV system at the Deepwater Generating Station of the Atlantic City Electric Co. in New Jersey which allows precision viewing of boiler water levels from a remote position.

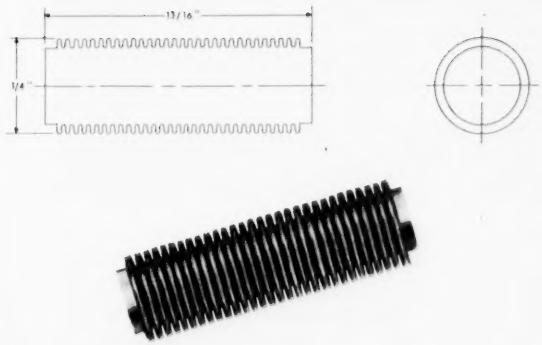
AUTOMATION STUDENT ROLAND DIETER EXPERIMENTS WITH POTENTIOMETER ▶



Allegheny High School science student, Roland Dieter, experiments with a potentiometer during a class in automation. He represented his school as a speaker on the potentiometer at the 15th annual Congress of Science Students at Buhl Planetarium. The course in automation (instrumentation and electronics) was the result of work by a committee of counsultants to the Pittsburgh Board of Education, chairmaned by *I&CS* editor, Milt Aronson.

MINIATURE BELLOWS

SAVE SPACE AND WEIGHT WITH RUGGED, MINIATURE ROBERTSHAW METALLIC BELLOWS

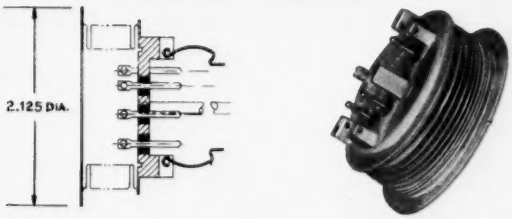


Seamless metallic bellows only ¼" and 5/16" O.D. permit further miniaturization in aircraft, missiles, instruments and other equipment. Available in a wide range of bellows metals to provide the desired strength and performance characteristics. Sensitive to temperature and pressure changes. Custom-engineered . . . but available in any quantity you need. Proved in dozens of miniaturized assemblies. **WRITE FOR BULLETIN F102!**

CIRCLE 23 ON READER-SERVICE CARD

FLUID EXPANSION CAPSULE

THERMAL EXPANSION OF OIL CONTROLLED BY SPACE-SAVING ROBERTSHAW FORMSET® BELLOWS



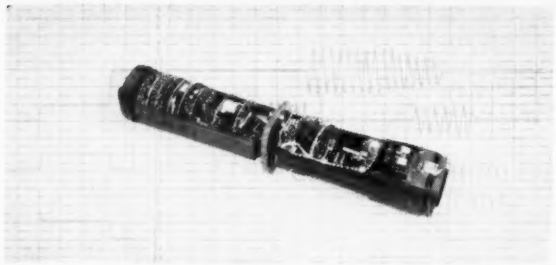
A low spring rate and a large stroke per unit of length, provided by a special Robertshaw Metallic Bellows called Formset, made possible this expansion capsule used in airborne gyroscopes. This assembly absorbs the thermal expansion of the oil which encases the gyroscope. Low spring rate in the bellows permits low pressure in the gyro. Space savings of up to 90% in bellows length can be achieved with Formset Bellows. Custom-engineered for instruments, transformers, relays and other applications using any fluid. **WRITE FOR ENGINEERING DATA SHEET F102!**

Robertshaw

BRIDGEPORT
THERMOSTAT DIVISION
Milford, Conn.

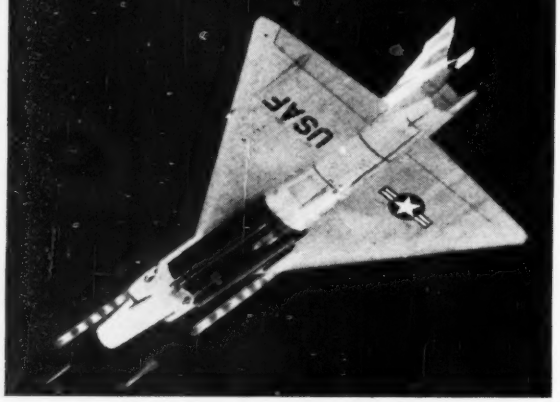
CIRCLE 24 ON READER-SERVICE CARD

THANKS TO BRISTOL CHARTS



AND HATHAWAY RECORDER

...THIS MISSILE MAN IS A SHARPSHOOTER



A compact airborne recorder assembly made by Hathaway Instrument Division of Hamilton Watch Company, Denver, Colorado, is used in simulated firings to train pilots in use of the Falcon air-to-air missile.

This rugged instrument records firing data on photo oscillographic paper, preprinted with accurate amplitude and reference lines by The Bristol Company.

Bristol's chart service developed the new process which permits accurate (±0.005") printing through photo sensitive emulsions and produces preprinted photo charts for oscillograph use.

This is just one example of Bristol's ability to design a chart to meet your special instrument requirements. On specially treated, coated or laminated stock, if required. With special punchings or printing to any desired mathematical law.

Your instrument is no better than the chart it records on. So for more information on Bristol's long experience in chart engineering and accurate, economical production methods, write: The Bristol Company, 154 Bristol Road, Waterbury, Conn. 9.23

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 25 ON READER-SERVICE CARD

ICS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1959 THRU JANUARY 18, 1960

	High	Low	Price As Of 1/18/60
ACF Industries	57	46 1/4	50 3/4
Aeroquip Corp.	38 1/2	23 5/8	34 1/8
Allis Chalmers	38 3/4	26 7/8	36 1/4
Amer. Chain & Cable	61 3/4	47 3/4	51
Amer. Mach. & Foundry	57 3/8	45 1/8	58
Amer. Mach. & Metals	59 3/4	41	55 1/4
American Optical	53 1/2	36 3/8	45 1/2
Amer. Tel. & Tel.	89	75 1/8	82 7/8
Ampex Corp.	137	61 1/4	102 1/2
Bausch & Lomb Optical	43 7/8	27	39 3/4
Beckman Instruments	74 3/4	36 1/4	64 1/2
Bell & Howell (new)	44 1/8	34 1/8	38 1/2
Bendix Aviation	89	61	70
Boeing Airplane	46 1/2	29 1/8	40 5/8
Bullard	24 7/8	15 1/2	16 7/8
Bulova Watch	20 5/8	13 3/8	17
Burroughs	45 3/4	28 3/4	33 1/4
Carborundum	56 3/4	37 3/8	48 3/8
Cinn. Milling Machine	47 5/8	35 1/4	37 3/4
Clevite	59 1/4	24 3/4	50 7/8
Columbia Broadcasting Sys.	48 3/4	35	42 3/4
Consol. Electronics	58 7/8	37 1/4	48 1/2
Cornell Dubilier	30 1/2	17 3/4	22 1/8
Corning Glass	154 3/4	89 3/4	139 3/4
Curtiss Wright	40 3/4	27 1/8	28 1/8
Cutler-Hammer	96	59 1/2	89
Daystrom	49 3/4	34	39 1/8
Douglas Aircraft	59 3/4	36 7/8	38
Eastman Kodak	112	75	103
Eaton Mfg.	46 7/8	36 3/4	43 1/4
Electric Auto-Lite	55 1/2	36 1/4	51 1/4
Elgin Watch	14	9 3/4	13 1/4
Emerson Electric	90 1/2	48 1/8	77
Food Mach. & Chem.	56 3/8	40	53
Garrett	50 7/8	38	46 1/2
General Controls	39 1/2	24	26 3/4
General Dynamics	66 1/2	42 7/8	50 1/8
General Electric	99 7/8	74	91 5/8
General Instrument	38 3/8	16 1/2	27 1/4
General Mills	37 5/8	28 1/4	29 1/8
Gen. Precision Equip.	60	31 1/2	48 1/2
Gen. Railway Signal	39 1/4	26 3/4	31 5/8
Gen. Tel. & Elect.	85 1/8	60	82
General Time	119 1/4	35	103 1/2
General Tire & Rubber	86 3/4	44 1/8	75 1/2
International Bus. Mach.	488	385 1/2	431
Internat'l. Tel. & Tel.	45 1/2	28	35 7/8
I-T-E Circuit Breaker	50 1/2	36 5/8	40
Lear Inc.	23 1/4	9 1/8	17 1/2
Litton Industries	73 1/2	57 5/8	60 5/8
Lockheed Aircraft	39 3/4	24 5/8	29 1/8
Magnavox	40 3/8	32 3/4	35 1/4
Mallory	50 7/8	35 3/4	44 1/2
Minneapolis-Honeywell	150	111 1/2	126
Minnesota Mining & Mfg.	182 1/2	111 1/2	165
Motorola	177	57 1/2	163 1/2
National Acme	63 1/2	50 1/8	54 3/4
National Cash Register	80	55 1/8	63 1/2
Neptune Meter	39 5/8	27 3/4	33
North American Aviation	52 5/8	30 1/4	38
Northrop Aircraft	44 3/4	24 5/8	28
Otis Elevator	89 1/4	61 1/2	86
Philco Corp.	36 3/4	21	32
Radio Corp. of America	73 1/4	43 1/8	63 3/4
Raytheon Mfg.	73 7/8	43 1/2	49
Reliance Electric	73	42 5/8	61 3/4
Rheem Mfg.	30 1/8	17 3/4	25 5/8
Robertshaw Fulton	59 3/4	31 5/8	49
Royal McBee	24 3/8	16	18 1/4
Sangamo Electric	51 1/2	35	42 5/8
Siegler Corp.	45 1/8	23 1/8	31 7/8
Sperry Rand	28 1/4	21 1/8	23 1/2
Square D	37 7/8	26 7/8	34 1/4
Standard Coil Products	23 3/4	13 3/4	15 5/8
Starrett (L.S.)	23 7/8	18 1/4	18 7/8
Stewart-Warner	33	29 3/4	29 1/4
Telautograph	13 3/8	8 5/8	9 1/2
Texas Instruments	193 1/2	61 1/4	163 1/4
Thompson-Ramo-Wooldridge	70 1/4	52	53
Tung-Sol Electric	54 1/4	34 1/8	38
Underwood Corp.	30 7/8	19 1/8	27 7/8
Union Carbide Corp.	150 1/2	120 1/2	143 1/2
United Shoe Machinery	65 1/4	45 5/8	56 1/2
Varian Associates	53	26 3/4	40 3/8
Wallace & Tiernan	52 7/8	36 1/4	46 3/4
Western Union	57	29 3/4	51 3/8
Westinghouse Air Brake	38 1/2	27 1/2	30 1/8
Westinghouse Electric	114	70 1/2	105 1/2
Worthington Corp.	84 1/2	59 1/2	61 1/4

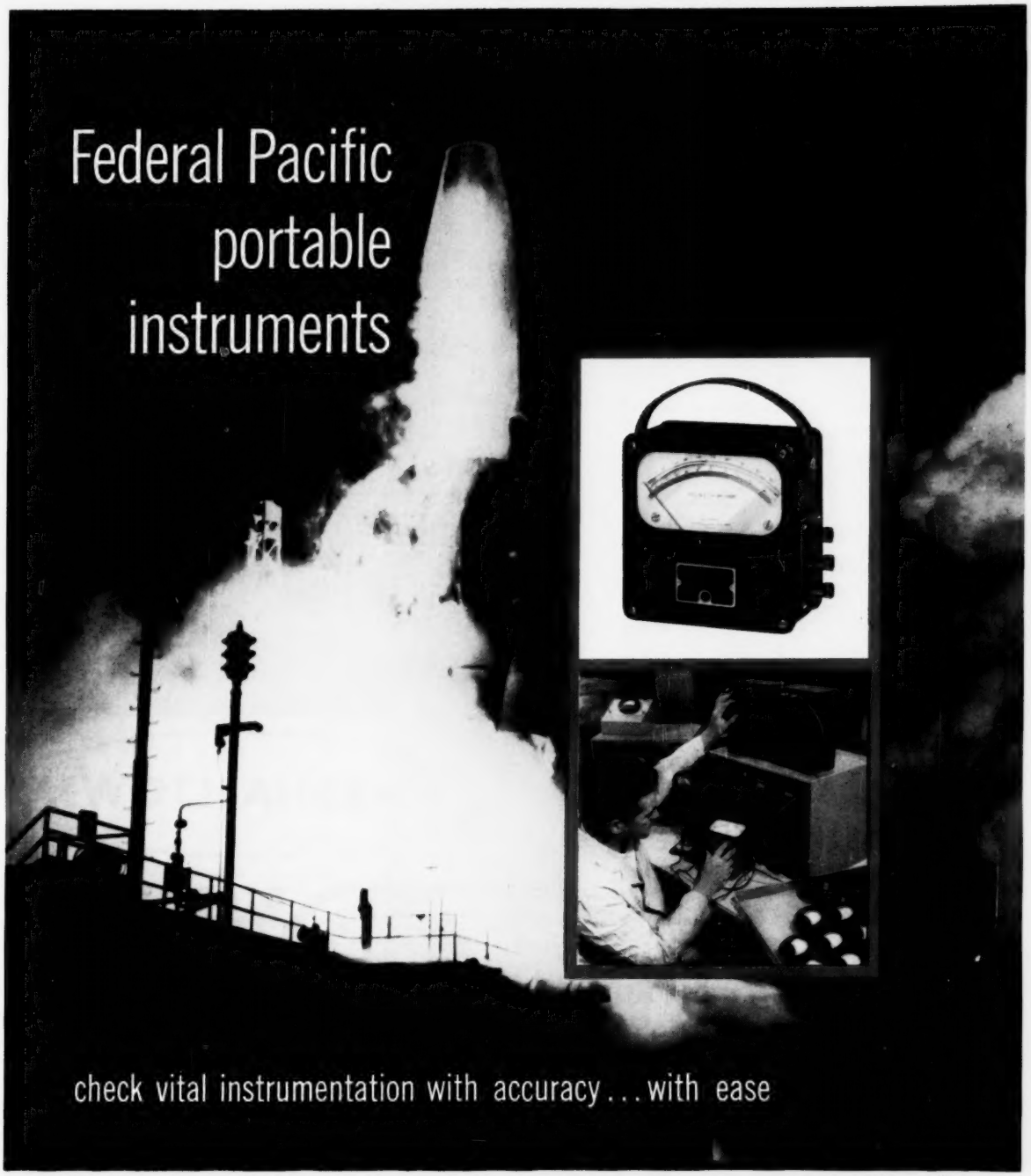
(1) Not traded - Bid and Asked

These prices and price ranges are given as printed in the Wall Street Journal.

AMERICAN STOCK EXCHANGE

PRICE RANGE 1959 THRU JANUARY 18, 1960

	High	Low	Price As Of 1/18/60
American Meter	47 1/4	38	45 Bid 46 Asked
Aro Equipment	29 3/4	20 3/4	24
Barry Controls "B"	26	13 3/4	21
Belock Instruments	27 7/8	10 3/8	15 5/8
Benrus Watch	9	5	6 1/2
Breeze Corp.	9 3/8	6 1/8	8
Clark Controller	30 3/8	19 5/8	22
Clarostat Mfg.	17 1/2	4	14
Clary Corp.	10 7/8	5 3/4	7 7/8
Cubic Corp.	65 5/8	29	60



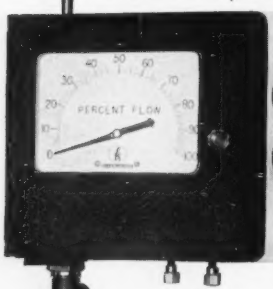
On the missile range... in delicate laboratory tests... in precision industrial production accuracy of instrumentation is vital. With Federal Pacific Portable Instruments, all types of precise equipment from simple voltmeters to complex missile tracking instrumentation can be calibrated and checked with ease—prior to use or during use. ■ Accurate, sturdy and versatile, Federal Pacific Portable Instruments are available in 6″ and 8″ models in the following types: A-C ammeter, milliammeter, voltmeter, wattmeter, frequency meter, power factor meter; D-C ammeter, milliammeter, microammeter, voltmeter, millivoltmeter, and voltammeter (6″ only). ■ Federal Pacific Portable Instruments can be furnished in single or multiple ranges. Can operate anywhere on a line to check current or voltage. Can operate in any position to check calibration. If you can reach it... you can check it. Write for Bulletin **4340**. Federal Pacific Electric Company, General Offices: Department 397, Newark 1, New Jersey.

FPE **FEDERAL PACIFIC ELECTRIC COMPANY**

The Best in Electrical Distribution and Control Equipment

CIRCLE 26 ON READER-SERVICE CARD

NEW/IMPROVED



PNEUMATIC TRANSMITTING ROTAMETER

New "position-balance" type Transmitter . . . air-signals fluid rates of flow to remote recorders, controllers . . . incorporates *exclusive* calibration adjustments (no cams) and drag-eliminating magnet design . . . scale suitable for any calibration . . . offers other features of real value all detailed in new Bulletin 18N. Write for a copy.

Schutte and Koerting COMPANY
INSTRUMENT DIVISION
2225 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.
CIRCLE 27 ON READER-SERVICE CARD

Stearns electro-magnetic miniature CLUTCHES
STYLE "SM"*
Now Available in **6 Standard Sizes**

* *Stationary Magnet*

- Installation-Proved Reliability
- Wide Range of Size . . . from ⅞ in. to 4¼ in. Torque from 25 oz in. to 240 lb in.
- Heavy-Duty Construction
- Moisture-, Corrosion-Resistant
- Fast, Easy Installation
- Stationary Magnet
- Rapid Actuation
- Self-Adjusting
- Available with extended hubs for pulley mounting

For complete data, request Bulletin No. 504-BV

Stearns ELECTRIC CORPORATION
120 NORTH BROADWAY
MILWAUKEE 2, WISCONSIN
CIRCLE 28 ON READER-SERVICE CARD

ICS STOCK REPORT *continued from page 194*

Du Mont Laboratories	9 7/8	6	8 3/4
Dynamics Corp. of Amer.	13 3/4	4 5/8	11
El-Tronics	2 1/4	1	1 5/8
Electronics Corp. of Amer.	16 7/8	7 1/2	9 1/8
Fairchild Camera & Instrument	157	125	136 3/4
General Transistor	45 3/8	25 3/4	24 1/8
Globe-Union	29 1/4	20 1/4	27 1/8
Hazeltine Corp.	33	23 1/2	27
International Resistance	25 3/8	7	23 5/8
Loral-Electronics	44 5/8	28 5/8	42 1/4
National Research	39 1/2	15 3/8	20 1/8
New Haven Clock	5 3/8	1 1/2	2 7/8
Nuclear Corp. of Amer.	4 1/4	1 3/4	3 1/4
Philips Electronics, Inc.	50 1/4	23 1/2	37 3/4
Pneumatic Scale	67	32	54 1/2
Servo Corp. of Amer.	43 1/2	14 5/8	21 5/8
Servomechanisms	18 1/4	9	10 5/8
Statham Instruments Inc.	43	23	32 1/8
Victoreen Instrument Co.	19 7/8	8 7/8	11 3/4
Waltham Prec. Instrument Co.	4 3/8	1 1/8	3 1/8

(1) Not Traded - Bid and Asked

These prices and price ranges are given as printed in the Wall Street Journal.

OVER THE COUNTER

	Quotation As Of January 15, 1960 Bid	Asked
Aerovox Corporation	14 1/8	15
Argus Corporation	33 5/8	34
Black Sivalls & Bryson Inc.	19 1/2	20 1/2
Eitel Mc Cullough	29 1/2	30 1/2
Electro Instruments	55	58
Electronics Associates	33	35 1/2
Erie Resistor Corporation	8 3/4	9 3/4
Fisher Governor Co.	17 1/4	18 1/4
Foxboro Company	75	78
Giannini Controls	37	38 1/4
Hagan Chemicals & Controls	34	39
Industro Transistor	15 1/2	16 3/4
Liquidometer Corp.	10	11 1/2
W. L. Maxson	12 1/8	12 3/4
Penn Controls	22 3/4	23 3/4
Speer Carbon, Inc.	24 1/2	25 3/4
Sprague Electric	56	58
Taylor Instruments	44 1/2	46 1/2
Telecomputing Corp.	13 5/8	14 1/2
Vitro Corp. of America	13 5/8	14 1/2

MARSHALLTOWN

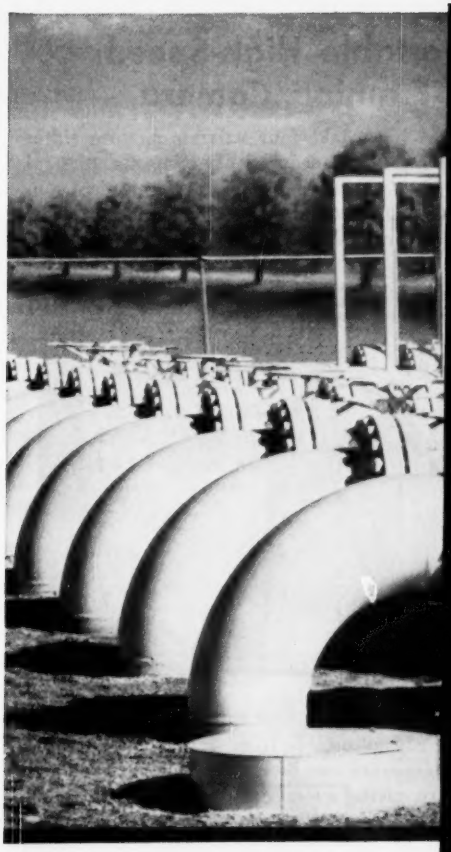
DIAPHRAGM GAUGE FOR ACCURATE PRESSURE MEASUREMENT IN OUNCES OR INCHES OF WATER

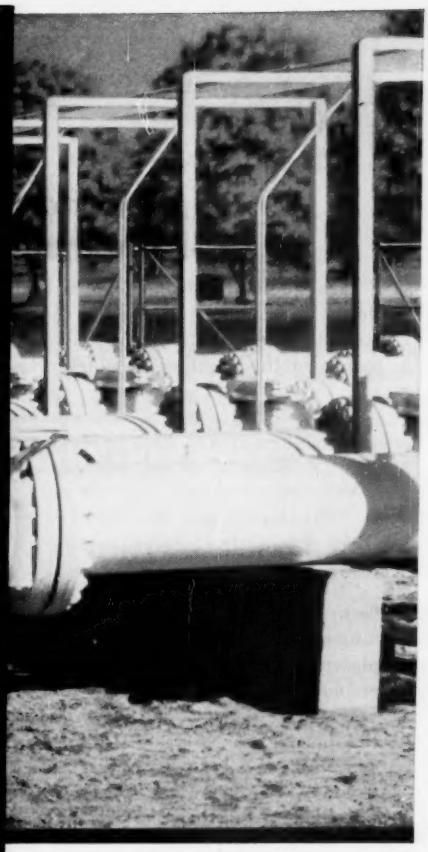
Marshalltown Figure 83 is an extremely sensitive gauge that uses a carefully seasoned bronze diaphragm to accurately measure very low pressures. It is used extensively on many types of natural gas installations for checking low pressures.

Available in standard dials (reading in inches of water) 0-15" -0-30" -0-60" -0-100" -0-160" . . . also in ounce graduated dials from 15 ounces to 5 pounds. 2½", 3½" and 4½" dial sizes mounted in black enameled steel case.

Write for details and price. LOOK TO MARSHALLTOWN FOR ONE OF THE MOST COMPLETE LINES OF INDICATING PRESSURE GAUGES MADE!

MARSHALLTOWN MFG. COMPANY
MARSHALLTOWN 3, IOWA
CIRCLE 29 ON READER-SERVICE CARD





ORIFICE METERS

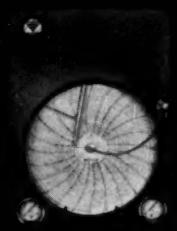
American-Westcott Dri-flo and mercury manometers in recording, indicating and integrating models—to 5000 psi working pressure.

GASCLOK

Gas or air-operated instrument power drive and timing unit for remote installations.

CANNON PENS

Controlled-flow capillary meter pens record up to a full year without refilling—eliminate chart smearing and blurring.



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Series A-88 Controllers, Transmitters & Receivers for control of continuous process variables. Telemetering Systems designed to meet your requirements.

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American's complete line of equipment sets the highest standards for accuracy and dependability. Ask your American representative about their applications and advantages for your measurement and control problems.

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INCORPORATED (ESTABLISHED 1836)

AMERICAN METER CO EST 1836 MEASUREMENT ENGINEERS

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IN CANADA: Canadian Meter Company, Ltd., Milton, Ontario Calgary • Edmonton • Montreal • Regina • Vancouver

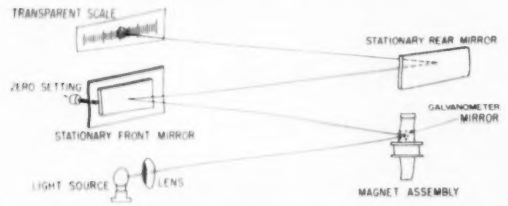
SUPPLIERS TO THE GAS INDUSTRY for Ironcase, Tinned Steelcase, Aluminumcase and Welded Steelcase Meters American-Westcott Orifice Meters • Instruments • Reliance Regulators • Apparatus • Valves

CIRCLE 30 ON READER-SERVICE CARD

ICS **BRIEFS**

Multiple-Reflection Galvanometer

In a spotlight galvanometer, a beam of light is reflected by a mirror attached to the coil and acts as a pointer. The sensitivity of the instrument depends mainly on the length of the pointer, i.e. on the distance

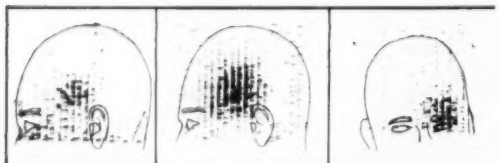


between mirror and scale, because this length determines the deflection of the light spot at a given displacement of the coil. If a long light beam is to be employed in a galvanometer containing the moving system and the scale in one unit, excessive length of the housing can be avoided by multiple reflection . . . (*From new 4-page Bulletin on Model 45, Photovolt Corp., 95 Madison Ave., New York 16, N. Y.*)

FOR THIS LITERATURE CIRCLE 165 ON READER-SERVICE CARD

Positron Scanner

When certain radioactive tracers are introduced, tumors take up these substances at different concentrations than normal regions. Radioactivity distribution measurements then made with the Positron Scanner Localization by this technique is a promising new diagnostic method . . .



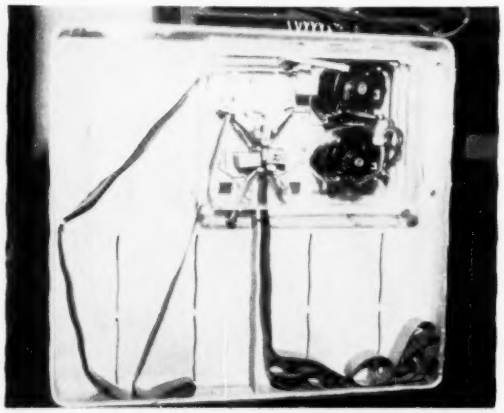
Coincidence positrocephalogram (PCG)	Asymmetrogammagram (AGC) asymmetry plot showing left to right distribution	A second PCG taken at another angle for additional information

The Positron Scanner utilizes positron (positive beta-particles) emitting radioisotopes. The isotopes emit positrons which are stopped almost immediately in tissue. When the positron stops, it combines with an atomic negative electron and both are completely "annihilated." The masses of this two electrons are converted to "back-to-back" gamma rays of about one-half an MEV each. These gammas are emitted simultaneously and in almost exactly opposite directions. The gamma rays are detected by scintillation crystals . . . (*From new 62-page Catalog A-4 "Atomic Instruments and Systems," Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass.*)

FOR THIS LITERATURE CIRCLE 166 ON READER-SERVICE CARD

Portable High-Speed Framing Camera

The Model 1 can take four separate pictures either in sequence or simultaneously. The time duration of each exposure is independently set by a convenient control. An external electrical signal will synchronize the exposure with any desired event. The time delay be-

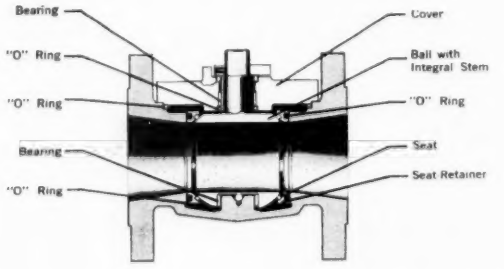


tween the synchronizing input signal and the exposure is continuously adjustable from 1 to 1000 microseconds. Any exposure can be triggered from any previous exposure, giving a total delay time of 4,000 microseconds. The Model 1 uses special image converter type tube shutters developed by Abtronics . . . (*From new 2-page pamphlet "Electronic Camera," Abtronics, Inc., 64 South P St., Livermore, Calif.*)

FOR THIS LITERATURE CIRCLE 167 ON READER-SERVICE CARD

Flo-Ball Valves

In the Hydromatics Bearing-Fixed Flo-Ball valve the ball is positively positioned by two non-lubricated bearings which absorb all line impact and shock, as well as reduce operating torque. To this we have added



two self-aligning and self-adjusting seats. Sealing force is held to the minimum for positive sealing and zero leakage. In fact, sealing force is increased with operating pressure. The complete valve is accessible from the top for cleaning and seat replacement without removing the valve from the line . . . (*From new 2-page leaflet, Hydromatics, Inc., Livingston, N. J.*)

FOR THIS LITERATURE CIRCLE 168 ON READER-SERVICE CARD

Engineered Dehydration in Pneumatic Systems

Sponge explains dew point ○
Clean air on low flow ●
Mag-Pneu-Power Trap ■
Refrigifilter: Inside story ◆

○ "Dew point" defined

Are you sure you use the terms "dew point" and "relative humidity" correctly? If there's any doubt, write for your copy of "THE DEW POINT STORY." A simple bath sponge analogy clarifies these terms in simple, easy-to-read language.

● Not a trace

What low-cost desiccant dehydrators are designed to provide clean, vapor-free air or gas to pneumatic equipment on dead end or low-flow service? Answer: Hankison Dehydrafilters.

With water adsorption capacity at 28%, and obtaining dew points as low as −67 F, Dehydrafilters effectively

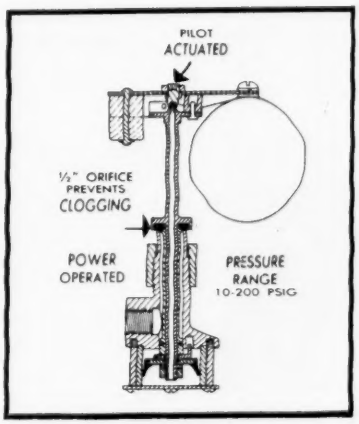
CM-1 Dehydrafilter. Cutaways show air inlet and outlet at top, desiccant and cartridge at bottom.

eliminate costly steam or electric tracing of the air lines. Several models are available. Capacities of 1 SCFM at 100 PSIG to 25 SCFM at 6000 PSIG can be accommodated.

■ A well-planned trap

Looking for a non-clogging trap? Note the drawing (top, next column) of the mechanism in our Mag-Pneu-Power Trap. Rising condensate pushes against the magnetically-held float until it snaps free. Pressure in the pneumatic system then drives the piston, which opens the discharge valve. Condensate is discharged in a split second through the large ½" orifice. It's simple – and trouble-free. For the occasional cleaning that's required, just open the blowdown petcock in case (not shown).

Mag-Pneu-Power Traps are used to discharge condensates and entrainments

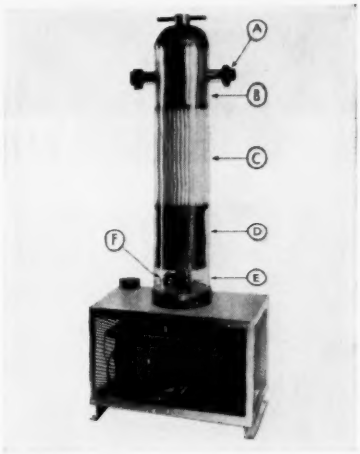


from all types of compressed air and gas lines, and to lend valuable assistance to air and gas dehydrating equipment. Stainless steel models are available for corrosive applications.

◆ Tells all

At right you see a demonstration model of the Hankison Refrigifilter. It gives you the inside story on obtaining instrument quality compressed air without cooling water, and regardless of ambient temperature variance.

In the unique Refrigifilter "package", incoming air at (A) is precooled in the counterflow heat exchanger (B). It then goes to the condenser-evaporator (D) where coils circulating Freon lower the temperature to 35° F *at pressure*, causing moisture and oil vapors to drop out into the collection chamber (E). Here the Mag-Pneu-Power Trap (F) discharges them through ½" orifice. From the condenser-evaporator, air passes through radial fin filter cartridge (C), which removes dirt, scale, and other solid contaminants. Thoroughly dried and cleaned, the air goes back into the counterflow heat exchanger where it is reheated and sent into the lines.



The Refrigifilter is simple, compact, costs less and does more than similar devices. It's easy to install, guarantees you micro-clean, dehydrated, oil-free compressed air all the time. Request Bulletin F-100 for the whole story—an exciting one indeed for anyone who uses pneumatic systems.

HANKISON CORPORATION, COLLEGE & PIKE, CANONSBURG, PA.

There's something here that interests me. Please send me more information about

- ☐ Dew Point
- ☐ Dehydrafilters
- ☐ Mag-Pneu-Power Automatic Traps
- ☐ Refrigifilters

NAME _____ TITLE _____

COMPANY _____

STREET _____

CITY _____ ZONE _____ STATE _____

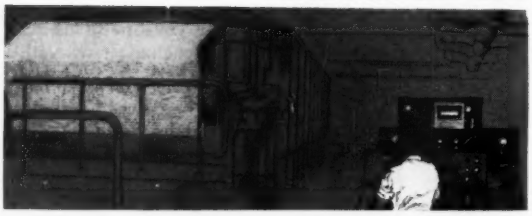
Hankison

CIRCLE 31 ON READER-SERVICE CARD

CONFIDENCE

where

control



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Temperature Controls for Industrial, Aircraft, Marine, Special Purpose

APPLICATIONS: Unlimited. For 28 years, we have been designing and manufacturing controls to fit individual needs.

MEDIUM: Air, liquid or hotplate.

RANGE: −150 to +650°F, adjustable.

SENSITIVITY: ±.5°F and up.

SWITCHES: Normally closed, open or double throw. Manual reset, high ambient and others available. 15 or 20 amps. 115/250 Volts AC. Also DC.

TYPES: Local mounted, remote bulb, skeleton or enclosed, calibrated or uncalibrated, single or multi-switch, indicating, explosion-proof, minimum size and special purpose.

OPERATION: Precision-made, liquid filled bellows combine with full rated snap-action switches for quick, accurate response to temperature change.

For further information request Condensed Catalog #400.

UNITED ELECTRIC

CONTROLS COMPANY

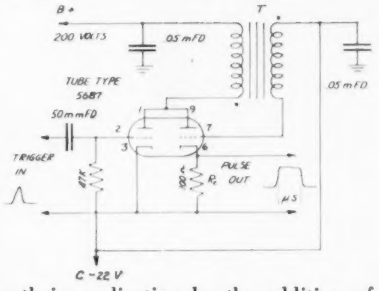
88 School St., Watertown, Mass.

CIRCLE 32 ON READER-SERVICE CARD

ICS **BRIEFS**

Miniature Pulse Transformers

It is impractical to impose both an OCL (Open Circuit Inductance) test and a BO (Blocking Oscillator) test upon a transformer due to circuit and core vagaries. One test or the other should be used, but not both. Circuit designers are urged to control pulse

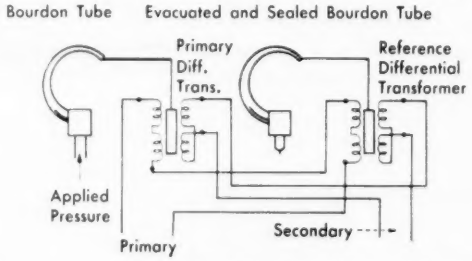


width in their application by the addition of an RC timing circuit. For every precise control, the inclusion of a delay line in the pulse forming circuitry is recommended. Operating temperatures are another important consideration in BO design. Typical values of temperature coefficient of pulse width are +.0012/°C for steel and −.003/°C for ferrite . . . (*From new* 24-*page Catalog C202, Pulse Engineering Inc.,* 560 *Robert Ave., Santa Clara, Calif.*)

FOR THIS LITERATURE CIRCLE 169 ON READER-SERVICE CARD

Differential Transformers

The operative principles of a differential transformer may be understood in the light of general iron core transformer theory. For simplicity, consider the so-called "ideal transformer" wherein the winding resistance, leakage inductances, winding capacitances, and core loss are all zero whereas the winding re-

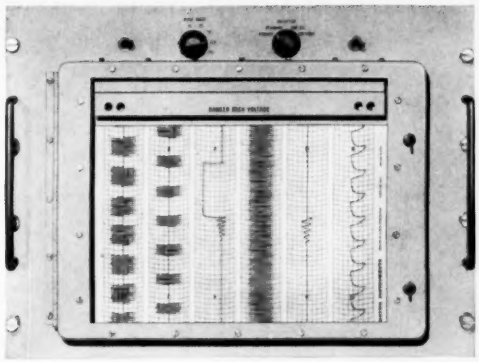


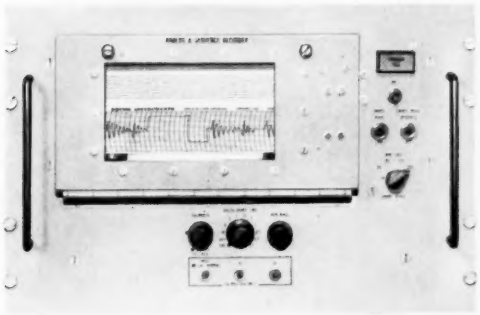
actances are infinite. In this theoretical transformer the currents in the windings are inversely proportional to the ratio of turns whereas the voltage ratio is directly proportional to the turns ratio regardless of the load . . .

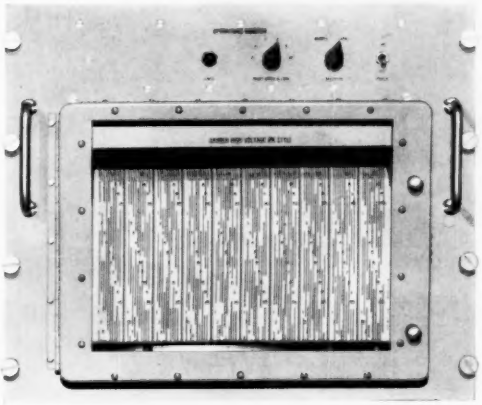
Device shown is used to indicate or control absolute pressures from 15 to 10,000 psia. Reference tube is evacuated and sealed. Signal output consists of algebraic sum of primary and reference transformers. (*From new* 32-*page "Handbook of Linear Transducers," Price* $2.00, *Automatic Timing & Controls, Inc., King of Prussia, Penna.*)

FOR THIS LITERATURE CIRCLE 170 ON READER-SERVICE CARD

CIRCLE 33 ON READER-SERVICE CARD ⟶







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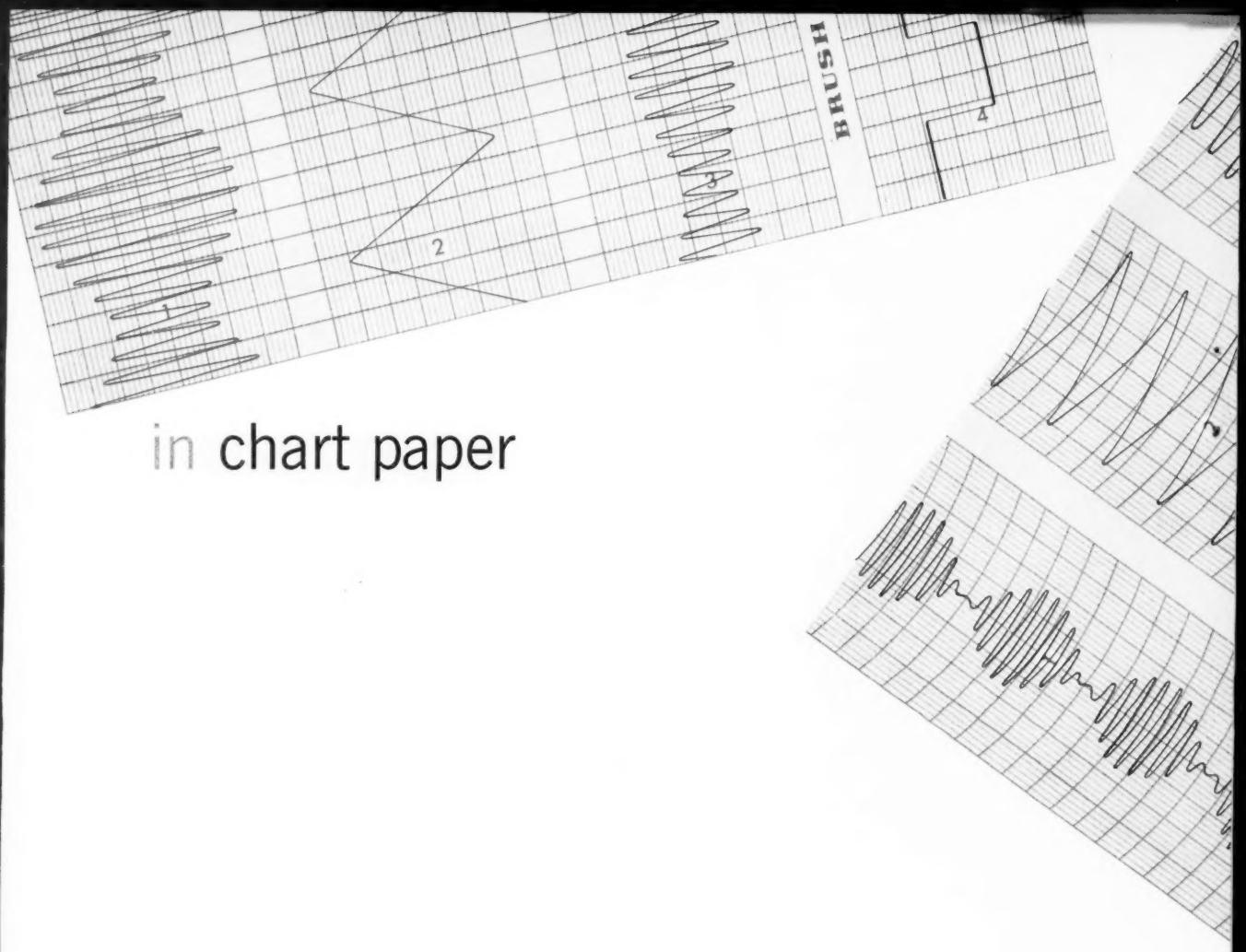
That's why they are performing every imaginable task of data acquisition and recording at U. S. and NATO installations throughout the world. These electric writing systems have proved their unexcelled reliability . . . from the Operations Monitor that will record 120 separate operations at the instant they occur . . . to the Analog and Sequence Recorder that simultaneously records both analog data and sequential events. And, they are built for maximum performance in the hands of non-technical personnel.

Brush equipment is already at work putting evaluation data in writing for a whole new generation of weapons. When the weapons become operational, Brush MIL Recorders are a vital part of the system. This experience is unique in the industry. *Before* prototype design becomes a problem—call, write or wire Brush for complete details.

brush INSTRUMENTS

DIVISION OF

37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO



in chart paper

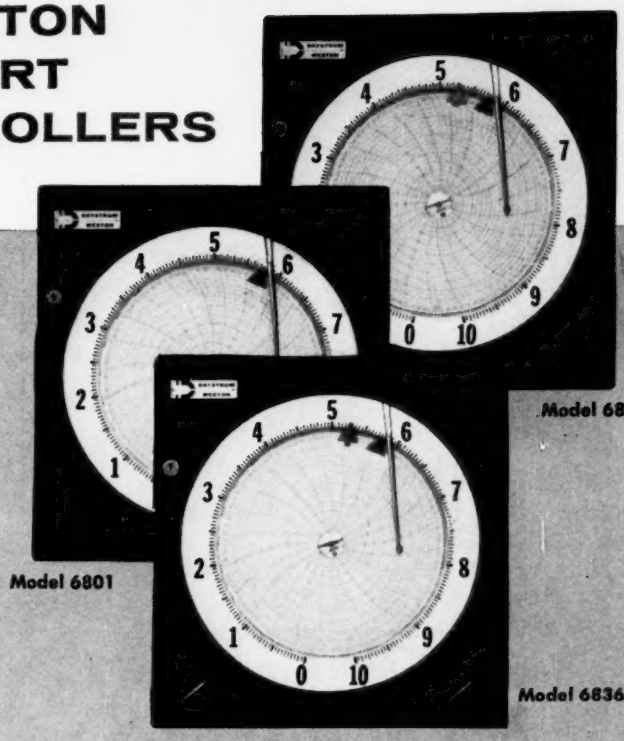
there
is
a
difference

brush INSTRUMENTS
DIVISION OF CLEVITE CORPORATION
37TH AND PERKINS CLEVELAND 14, OHIO

Only Brush Chart Paper is designed as an integral component of precisely engineered Brush Direct Writing Recording Systems. The full potential of these systems cannot be realized unless *all* of the original components are utilized. They're engineered as a *total* entity. Imitation papers cannot match the precision ruling, dimensional stability and super-smoothness of Brush Chart Paper. Take no chances—specify *Brush* and you can rely on your records being accurate, permanent, easily read and easily reproduced. Stocks available from strategically located branches and sales representatives throughout the United States and Canada.

Write for samples of actual tracings on Brush Chart Paper. Ask for "Check the Record".

DAYSTROM-WESTON CIRCULAR-CHART RECORDERS CONTROLLERS



there's unequalled value in this newly designed series...

thanks to **UNITIZATION***

All the features of the famous Weston strip-chart instruments are available in this new line of potentiometer and Wheatstone Bridge recorders and recorder-controllers. And there's a bonus in readability and easy maintenance. The basic recorder designs (Models 6801 & 6821) show their versatility in adapting to either pneumatic (6836 & 6856) or electric (6833 & 6853) control—of the 2-position, proportioning, or differential-gap varieties.

Here are some of the other dividends *unitization* brings you in this great new series:

EASIEST MAINTENANCE . . . revolutionary D-Pak Constant Voltage Supply Units eliminate batteries, standard cells and standardizing mechanisms in potentiometers. Wheatstone Bridges are equipped with Battery Eliminators. Every component is easily accessible; there's no jungle of wires to hamper inspection and servicing.

READABILITY . . . 12-inch charts, with full-scale pen travel of 4⅝ inches. 320° concentric indicating scales are 33⅞ inches long. Universal mounting permits use in the most advantageous locations.

INTERCHANGEABLE PARTS . . . exclusive universal range standards can be changed in seconds. A single slide-wire and amplifier will serve any WESTON recording potentiometer. This means *lowest spare-parts inventories.*

For more complete information, call your local WESTON representative . . . or write to Weston Instruments, Division of Daystrom, Inc., Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Ont. Export: Daystrom Int., 100 Empire St., Newark 12, N. J.*

*** UNITIZATION:**
the grouping of related components—in Daystrom-Weston Instruments—in the simplest, most serviceable, most efficient manner.

DAYSTROM-WESTON

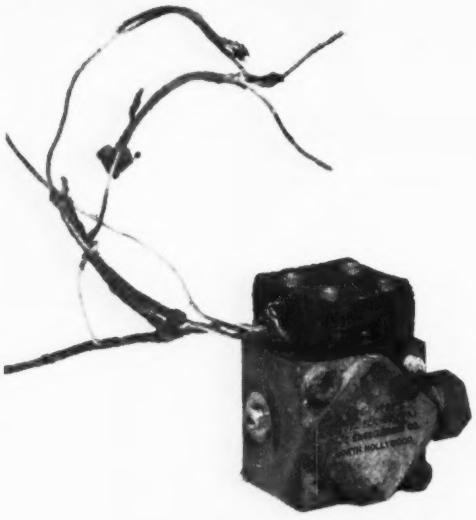
Industrial Instruments

A DAYSTROM UNIT

←CIRCLE 34 ON READER-SERVICE CARD

CIRCLE 35 ON READER-SERVICE CARD

Case History No. **2**



PACE

TRANSDUCERS CAN TAKE IT !

PACE Model P21 transducers were used by a Government Agency to measure differential pressure at an engine test facility. The transducer shown above was caught in an explosive blast and engulfed by fire.

Upon being returned to the factory, the transducer was tested and found to be operative and on calibration. With a new cable and fittings, it was as good as new.

PACE builds a complete line of rugged, reliable magnetic reluctance transducers, designed to withstand extreme pressure overloads and the abuse encountered in normal and abnormal applications.

For detailed information on these transducers, PACE Instrumentation Systems and Thermocouple Reference Junctions, phone or write to the factory or contact your local PACE Engineering Company representative.

PACE *engineering company*
13035 Saticoy Street — North Hollywood, California
TRiangle 7-7139

CIRCLE 36 ON READER-SERVICE CARD

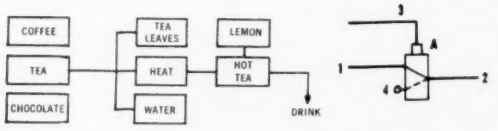
ICS **BRIEFS**

Pneumatic Circuitry (Moleculonics)

The easiest identification of the basic logic functions have been termed NOT, OR, AND and MEMORY . . . A fifth function is often called TIME—actually a limited MEMORY action . . .

HUMAN EXAMPLE

Take the simple problem of a man and a hot drink. Of the three choices he must choose Coffee or Tea or



Chocolate, and he cannot proceed until he has picked one OR the other. To make Tea, if this is his choice, he must have tea leaves AND heat AND water. Once made, he is now ready to drink; if he cannot drink unless there is lemon then the NOT circuit is invoked. A simple explanation, but it may serve those of you who have not had much dealings with "logic control".

Fig. illustrates, by using an air-piloted 3-way valve, the NOT circuit principle. Here, input 1 continues through the output 2 until interrupted by impulse 3. After the action by impulse 3, line 1 is stopped at the valve while line 3 is connected to line 4—line 4 is shown as atmosphere (exhaust) but it could be plugged . . . (*From new 54-page pocket-size Booklet "Modernair Moleculonics," Modernair Corp., 5007 Brookpark Rd., Cleveland 34, Ohio.*)

FOR THIS LITERATURE CIRCLE 171 ON READER-SERVICE CARD

Tape Reliability

The reliability of magnetic tape depends primarily on two factors—the magnetic iron oxide coating and the tape base.

Currently, instrumentation tapes are made on two bases: DuPont's "Mylar" polyester film and cellulose acetate film (also produced by DuPont). In some applications, acetate has performed satisfactorily as a tape base. But the growing need for increased reliability has created a trend toward "Mylar." This trend is a result of the superiority of "Mylar" in those physical properties which influence the function of finished tape:—coefficient of humidity expansion of 1.1×10^{-5} inch/inch/%R.H. (compared to 15×10^{-5} for acetate); fewer signal dropouts due to cupping; greater shock tensile strength; greater resistance to stretching, increased repeatability without distortion; greater toughness; longer storage life.—(*From new 10-page Brochure "How Magnetic Instrumentation Tapes of Mylar Provide Maximum Reliability," E. I. DuPont de Nemours & Co., Wilmington 98, Del.*)

FOR THIS LITERATURE CIRCLE 172 ON READER-SERVICE CARD

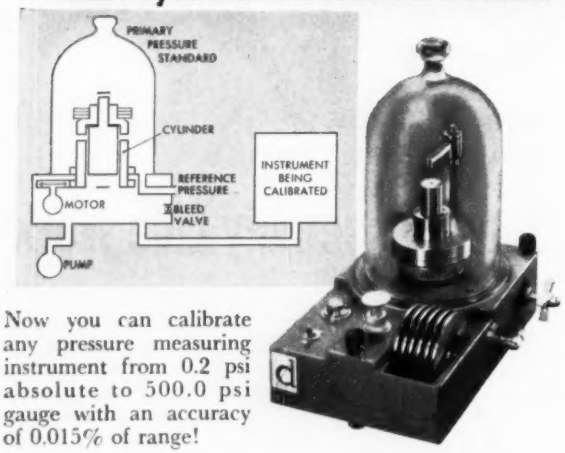
MOORE PRODUCTS CO.
H & Lycoming Sts., Philadelphia 24, Pa.

Offices: **ATLANTA, BOSTON, CHARLOTTE, CHICAGO, CLEVELAND, DETROIT, HOUSTON, LOS ANGELES, LOUISVILLE, NEW ORLEANS, NEW YORK, PHILADELPHIA, PITTSBURGH**

In Canada: Moore Instrument Co., Ltd.—**TORONTO** *Branch:* **MONTREAL**

CIRCLE 37 ON READER-SERVICE CARD

NEW! PRIMARY PRESSURE STANDARD with Cyclic Bi-directional Rotation



Now you can calibrate any pressure measuring instrument from 0.2 psi absolute to 500.0 psi gauge with an accuracy of 0.015% of range!

- Exclusive cyclic bi-directional rotation of cylinder minimizes lift error
- Four pressure ranges
- Use any reference pressure from zero to one atmosphere absolute
- Self-contained pressure source provides pressure up to 15 psi

Write for Technical Bulletin on Primary Pressure Standard.

DYNAMETRICS CORPORATION

Northwest Industrial Park, Dept. 18 Burlington, Mass

CIRCLE 40 ON READER-SERVICE CARD

ARE YOU BOXED IN?

Data Systems can lift the lid! The expansion program now underway at Data Systems will double the engineering department in six months. Many challenging career positions with almost unlimited opportunities for advancement are now open to computer design and development engineers. You will work on automatic industrial controls, special purpose digital data processing equipment, and advanced mark sensing systems involving high speed paper handling devices. Pay schedules are excellent; working conditions are ideal. A new facility is planned for the Newport Beach (Southern California) area in the immediate future.

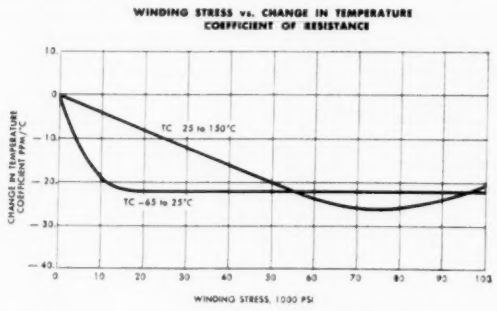
If you are tired of being boxed in, contact John Flynn, Area #14

Data Systems Dept.
NORDEN DIVISION
UNITED AIRCRAFT CORPORATION
13210 Crenshaw Boulevard • Gardena, California

CIRCLE 41 ON READER-SERVICE CARD

ICS BRIEFS

and temperature coefficient which may be expected of Chromel-R when wound at various tensions around supports having a thermal coefficient of expansion less than that of the wire itself. It the wire were wound


WINDING STRESS vs. CHANGE IN TEMPERATURE COEFFICIENT OF RESISTANCE
CHANGE IN TEMPERATURE COEFFICIENT PPM/°C
TC 25 to 150°C
TC −65 to 25°C
WINDING STRESS, 1000 PSI

around supports having a greater coefficient of expansion, these curves would reflect corresponding increases in the wire's electrical resistivity and temperature coefficient . . . (*From new 8-page Bulletin* 111, *Hoskins Mfg. Co., 4445 Lauton Ave., Detroit 8, Mich.*)

FOR THIS LITERATURE CIRCLE 174 ON READER-SERVICE CARD

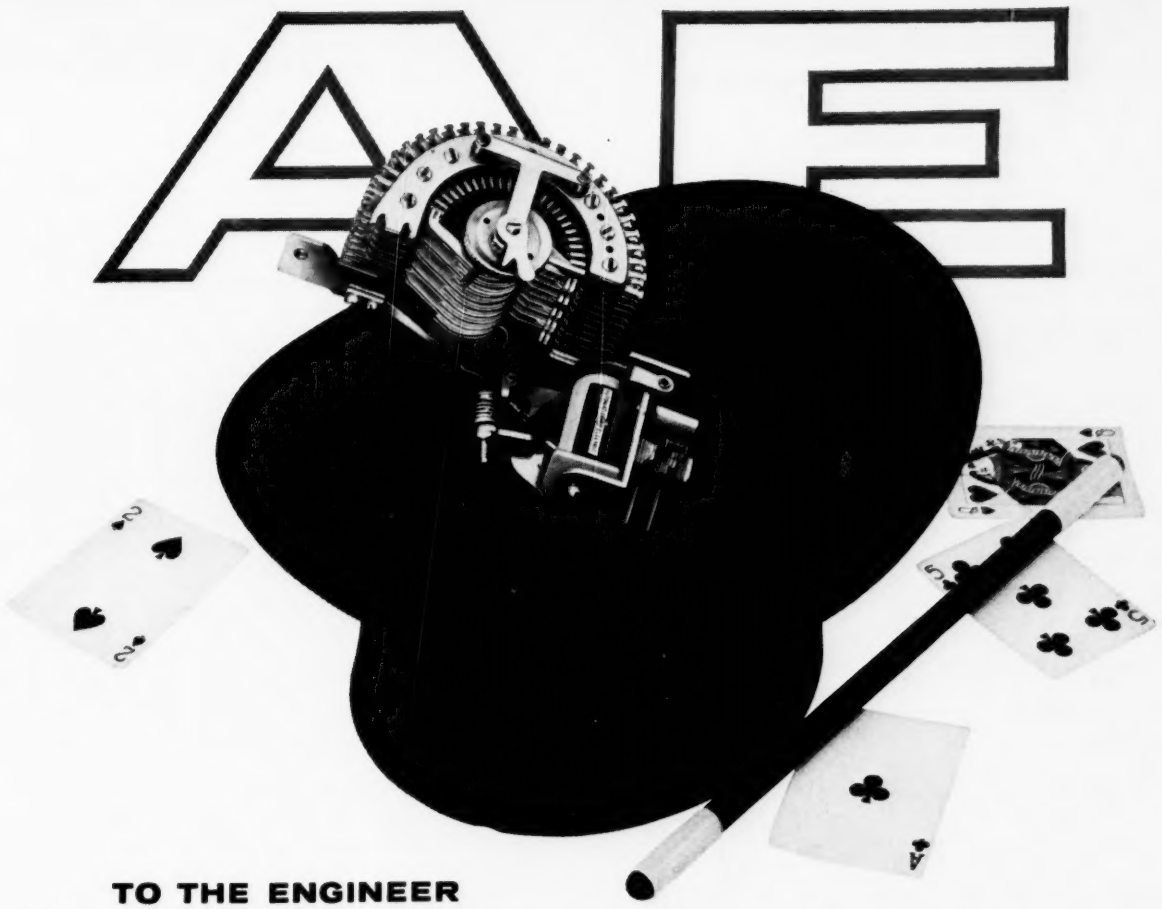
Industrial Temperature Measurement and Control

There are 8 ways of responding to temperature: (1) Changes in pressure . . . (2) changes in liquid volume . . . (3) differences in the expansion of metals

Response To Temperature	Temperature Range Of Application Deg. F
Changes in Pressure	
Kerosene Filled	250-700
Alcohol Filled	200-400
Ether Filled	100-300
Sulfur Dioxide Filled	20-250
Nitrogen Filled	0-500
Changes in Liquid Volume	
Mercury Filled (Steel Bulb-Capillary)	—30-1100
Mercury Filled (Ordinary)	— 4-680
Mercury Filled (Nitrogen Covered)	—38-1000
Alcohol Filled	—50-300
Glycerine Filled	30-500
Differences in Expansion of Metals	
Bimetallic Strips	0-700
Bimetallic Rods	300-1000
Changes in Electrical Resistance	
Electrical Resistance Thermometer	—400-1800
Thermocouples	
Base Metal (Copper-Constantan)	50-660
Base Metal (Iron-Constantan)	100-1650
Base Metal (Chromel-Alumel)	300-2000
Rare Metal (Platinum-Rhodium)	300-2800
Photo-Electric Effects	
Radiation Pyrometer	1000 up
Changes in Color	
Optical Pyrometer	1400 up
Changes in Melting Points	
Fusion Pyrometers	1100-3600

. . . (4) changes in electrical resistance . . . (5) thermocouples . . . (6) photo-electric effects . . . (7) changes in color . . . (8) changes in melting point . . . (*From new 24-page Bulletin* 101, *Partlow Corp., New Hartford (Suburb of Utica), N. Y.*)

FOR THIS LITERATURE CIRCLE 175 ON READER-SERVICE CARD



TO THE ENGINEER

who can use a little honest trickery

There's more than one way of skinning a cat —or making ideas *work* automatically. And AE has a bag-full.

That's because AE has had years of experience in making relays and stepping switches work wonders in automatic telephone exchanges—*and* in automatic control devices.

If you can use some down-to-earth magic in your designs, AE engineers will be glad to help. And you may well find that their suggestions can simplify the control package.

They can also show you why AE relays and stepping switches cost you less in the long run.

For instance, the AE Type 45 Stepping Switch, illustrated, has a free-floating pawl that never binds, never breaks, eliminates the necessity of ever readjusting armature stroke, does away with double-stepping or overthrow. And the switch usually outlasts the equipment it's built into!

You'll also be interested in knowing that AE is equipped to deliver completely wired and assembled control units designed to your specifications.

Want more information? Just write the Director, Industrial Products Engineering, Automatic Electric, Northlake, Illinois. Ask for Circular 1698-H: *Rotary Stepping Switches;* Circular 1702-E: *Relays for Industry;* and our new 32-page booklet on *Basic Circuits.*

AE CAN DO

AUTOMATIC ELECTRIC

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE 42 ON READER-SERVICE CARD

even in toughest environments,

CEC's 4-123 transducer

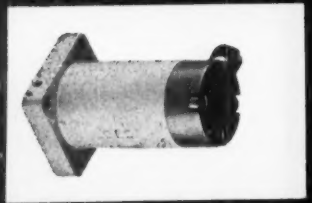
DETECTS VIBRATION IMMEDIATELY

A hint of vibration in a jet engine or in engine test cells is detected instantly by CEC's omnidirectional 4-123 vibration transducer. This rugged pickup assures a frequency response of 45 to 2000 cps . . . provides constant damping over an operating temperature range of −65°F. to +500°F.

Hermetically sealed against sand and dust, the 4-123 functions perfectly in oily, corrosive and humid atmospheres. It weighs only 4.25 oz., including connector, and is 2⅛″ high.

Wherever unbalance is present—in engines, machinery, motors or generators—CEC's line of vibration transducers ensures fast detection, quickly helps solve your vibration problems.

For complete information, call your nearest CEC sales and service office or write today for Bulletin CEC 1596-X14.



Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

IRE EVENTS

February 18-19
Twin City Section of I.S.A. 5th Annual North Central Area Automation Symposium, Lowry Hotel, St. Paul, Minn. For information write R. E. Hopper, International Div., Minneapolis-Honeywell, 2753 Fourth Ave., S., Minneapolis 8, Minn.

February 24
Los Angeles Sec., American Society for Quality Control Reliability Symposium, Statler Hilton Hotel, Los Angeles, Calif. For information write Irving Quart, 12721 Welby Way, N. Hollywood, Calif.

February 25-26
Seventh Scintillation Counter Symposium, Hotel Shoreham, Washington, D. C. For information write G. A. Morton, RCA Laboratories, Princeton, N. J.

March 16-18
Twenty-Third Annual Short Course for Superintendents and Operators of Water and Sewage Systems, will be held on campus of Louisiana State University. For information write Fred H. Fenn, College of Engineering, Louisiana State University, University Station, Baton Rouge 3, Louisiana

March 17-18
Synchro Design and Testing Symposium, sponsored by Dept. of the Navy Bureau of Naval Weapons, Dept. of Commerce Auditorium, 14th and Constitution Ave., N.W. Washington, D. C. For information write U.S. Naval Weapons Plant (751:31), Washington 25, D. C.

March 21-24
IRE National Convention, Coliseum and Waldorf-Astoria Hotel, New York, N. Y. Write E. K. Gannett, Institute of Radio Engineers, 1 East 79th St., New York 21, N. Y.

March 23-24
10th Annual Iron & Steel Conference, Pick-Roosevelt Hotel, Pittsburgh, Pa. For information write R. E. Blackwell, Box 1346, Pittsburgh 30, Penna.

March 24-25
1st Annual Symposium on Human Factors in Electronics, New York City. For information write R. R. Riesz, Chmn. Papers Procurement Comm., c/o Bell Telephone Labs, Murray Hill, N. J.

March 26
Fourth Annual Symposium on Recent Advances In Programming Methods, Ohio State University, Columbus, Ohio. For information write R. K. Kissinger, Nationwide Insurance Companies, 246 N. High St., Columbus, Ohio.

April 4-6
Third Annual ISA Symposium on Progress and Trends in Chemical and Petroleum Instrumentation, Hotel Sheraton, Rochester, N. Y. For information write ISA, 313 6th Ave., Pittsburgh 22, Pa.

← CIRCLE 43 ON READER-SERVICE CARD

April 4-5
Solar Energy Symposium, sponsored by the University of Florida and the American Society of Mechanical Engineers, on campus of University of Florida. For information write John C. Reed, Mechanical Engineering Department, University of Florida, Gainesville, Fla.

April 5
New Jersey Section of ISA Symposium on Computers In The Process Industry, Hotel Essex House, Newark, N. J. For more information write D. L. Lightstone, Robertshaw-Fulton Controls Co., 44 Grand Ave., Englewood, N. J.

April 6-8
Institute of Environmental Sciences National Meeting, Biltmore Hotel, Los Angeles. For information write Bruno Forscher, 16446 Bircher St., Granada Hills, Calif.

April 12-14
32nd Annual PIEA-PESA Conference and Exhibition, Municipal Auditorium and Muehlbach Hotel, Kansas City, Missouri. For information write Duane L. Thoe, Petroleum Industry Electrical Association, 2223 Dodge St., Omaha 2, Nebraska.

April 18-19
Third Annual Conference on Automatic Techniques, sponsored by the ASME, IRE and AIEE, Cleveland, Ohio. For information write J. H. McRainey, Room 530, 1213 W. 3rd St., Cleveland 13, Ohio.

April 19-21
10th Annual Symposium of Active Networks and Feedback Systems Engineering Societies Bldg., 33 W. 39th St., New York. Microwave Research Institute of Polytechnic Institute of Brooklyn. For information write Herbert J. Carlin, Microwave Research Institute, 55 Johnson St., Brooklyn 1, N. Y.

April 20-22
Texas A & M Symposium on Instrumentation for the Process Industries, will be held on campus of Texas A & M. For information write N. E. Welch, Chemical Engineering Dept., Agricultural and Mechanical College of Texas, College Station, Texas

April 27-29
Sixth Annual Southern ISA Conference & Exhibit and First Pulp and Paper Division Symposium, Pensacola, Florida. For information write W. H. Matthews, P. O. Box 4426, Pensacola, Fla.

May 3-5
1960 Western Joint Computer Conference, Jack Tar Hotel, San Francisco, Calif. For information write H. M. Zeidler, Stanford Research Institute, Menlo Park, Calif.

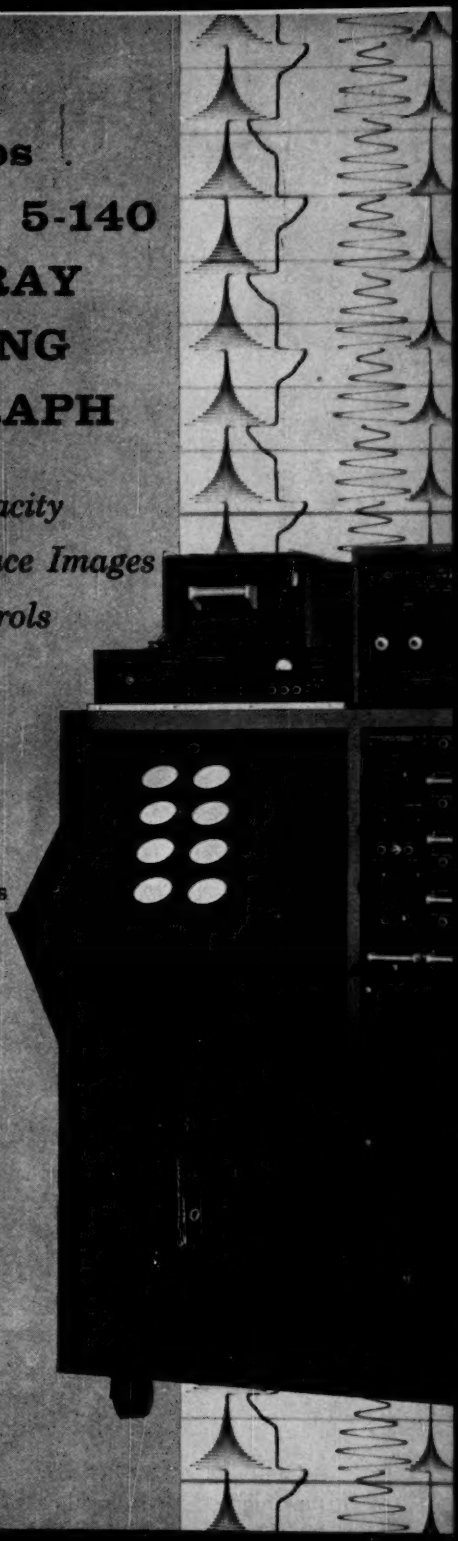
May 9-11
Annual PGMTT Symposium, sponsored by IRE Professional Group on Microwave Theory and Techniques, Hotel del Coronado, Coronado, Calif. For information write David B. Medved, CONVAIR, Division of General Dynamics, Mail Zone 6-172, Box 1950, San Diego 12, Calif.

June 16-18
Fifth Annual Symposium and Exhibit of American Scientific Glassblowers Society, Penn-Sheraton Hotel, Pittsburgh, Penna. For information write W. E. Barr, Gulf Research & Development Company, P. O. Box 2038, Pittsburgh 30, Penna.

CIRCLE 44 ON READER-SERVICE CARD →

RECORD 100,000 cps WITH CEC's 5-140 CATHODE-RAY RECORDING OSCILLOGRAPH

- *16-Channel Capacity*
- *Ultra-Sharp Trace Images*
- *Pushbutton Controls*



This completely integrated recording system combines the high frequency response of cathode-ray tubes with a precision optical system... provides continuous, high-resolution oscillograph records on standard film or paper... offers eight record speeds* from 3 to 400 ips with local or remote operation. There is virtually no limit to applications for the 5-140, particularly in such diversified test programs as missile flights, rocket engine tests, jet engine and propeller studies, land and sea blast analyses, rocket sled tests, wind tunnel tests, tape playback in data reduction centers, and nuclear tests.

*To 800 ips with 5-038 Hi-Speed Magazine

For complete information, write today for Bulletin CEC 1589-X1.

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

Foxboro Consotrol control panel at W. R. Grace & Co. polyethylene plant in Baton Rouge, Louisiana.

Foxboro Consotrols* help put 50 million pound

"Perfect instrument performance on start-up," reports W. R. Grace & Co.'s

50 million pounds of GREX — W. R. Grace & Co.'s new high strength plastic resin — that's the capacity of their new Polymer Chemicals Division plant in Baton Rouge, La. Instrumentation for the 30 acre, multi-million dollar facility was supplied by The Foxboro Company.

"Our main Foxboro panel was a big help in getting this temperature-controlled process off to a successful start," reports instrument supervisor Al Farris. "Over 95% of the variables on the panel are controlled — many of the key ones are part of cascade control systems. Instrument performance on start-up was perfect."

Grace instrument men like their Foxboro pneumatic Consotrols for other reasons as well: The M/54 Recorder's 4-inch vertical-travel chart . . . the drawer-type pull-out feature of Consotrols . . . the fact that in 18 months of operation not a single Consotrol has needed re-calibration.

Foxboro Consotrol instrumentation includes con-

*Reg. U.S. Pat. Off.

CIRCLE 45 ON READER-SERVICE CARD

polyethylene plant on stream without a hitch

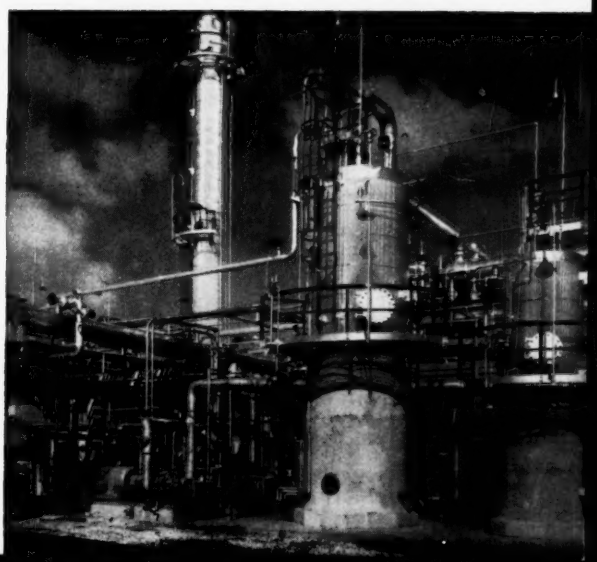
Polymer Chemicals Division

trol functions for all types of processing requirements — auto-selector . . . cascade and ratio systems . . . automatic batch control. Get the complete story by writing for Bulletin 13-18. **The Foxboro Company, 462 Norfolk St., Foxboro, Mass.**

CIRCLE 45 ON READER-SERVICE CARD

FOXBORO

REG. U.S. PAT. OFF.

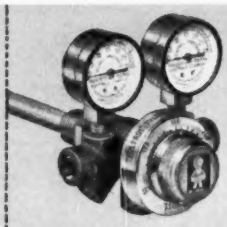


30-acre W. R. Grace & Co. Polymer Chemicals Division plant has 50 million pound annual capacity. First product — new high strength plastic resin tradenamed GREX.

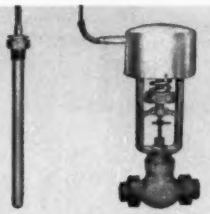
FROM SELF-OPS TO INDICATING CONTROLLERS . . .

Sure Control at Low Cost ...and Quality All the Way!

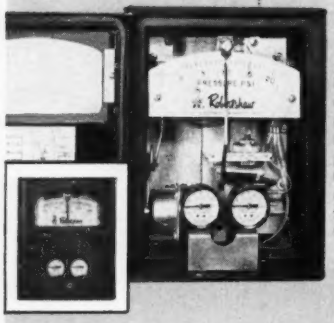
1135 FultroPilot . . . for positive remote control through air signal to control valve, damper actuator, etc., from fast-response thermostat.



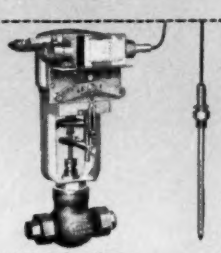
1100 FulTrol® Series . . . controls liquid or air temperatures in conjunction with valves, dampers, etc. Adjustable proportional band; wide ranges.



1004 Series . . . closest temperature control in the self-ops field. Available in 40° adjustment ranges from −35°F to +425°F. (Plus 8 other styles.)



1150 Series . . . an indicating pneumatic controller with greatest field serviceability; proportional action (.5% to 200%), automatic reset, fully compensated thermal system.



1110 FultroMatic . . . complete temperature control system in one air-actuated package: temperature controller, pneumatic control valve, positive valve positioner.

From the rugged simplicity of self-ops to the more complicated requirements of an indicating controller, Robertshaw answers your temperature control needs — efficiently and economically.

And whichever Robertshaw instrument best fits your particular job, you know there's quality all the way . . . quality of design, construction, performance.

Check the Robertshaw temperature and pressure controls for *your* needs. You'll find them shown in detail in Catalog A-CL. **Fulton Sylphon Division, Robertshaw-Fulton Controls Co., Knoxville 1, Tenn.**

Robertshaw

MR CONTROLS

CIRCLE 46 ON READER-SERVICE CARD

ICS BOOKS

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses, by John F. Rider and Seymour D. Uslan [c1959] John R. Rider Publisher, Inc., 116W 14 St., New York, N. Y., 1305 p. +xix, 11". clothbound $21.95. Second edition of this "bible" of oscilloscopes includes new types, with theory, analysis of circuitry, maintenance, and applications. Contains new data on probe's, on scope photography, and new sections on pulse measurements and square wave testing.

CIRCLE 176 ON READER-SERVICE CARD

Grundlagen der selbsttaetigen Regelung, (Fundamentals of Automatic Control) edited under supervision of Heinrich Kindler [c1959] R. Oldenbourg Verlag, Munich, West Germany, 727 p., 9½", clothbound $10.00. Vol. 2, titled "Some Problems from the Theory of Non-Linear Automatic Control Systems," explains typical non-linear characteristics of automatic control systems; introduces the idea of the phase-space and its application for solving of problems; gives methods of approximation for investigations of periodic happenings, methods for analyzing of relay systems, and graphic-analytic methods for the representation of transfer functions.

CIRCLE 177 ON READER-SERVICE CARD

A Treatise on Algebraic Plane Curves, by Julian Lowell Coolidge, Dover Publications, Inc., 180 Varick St., New York 14, N. Y., 513 p+xxiv, 8", paperbound $2.45. Unabridged reprint of a previously published book covering the field in a thorough manner. Contains extensive bibliography.

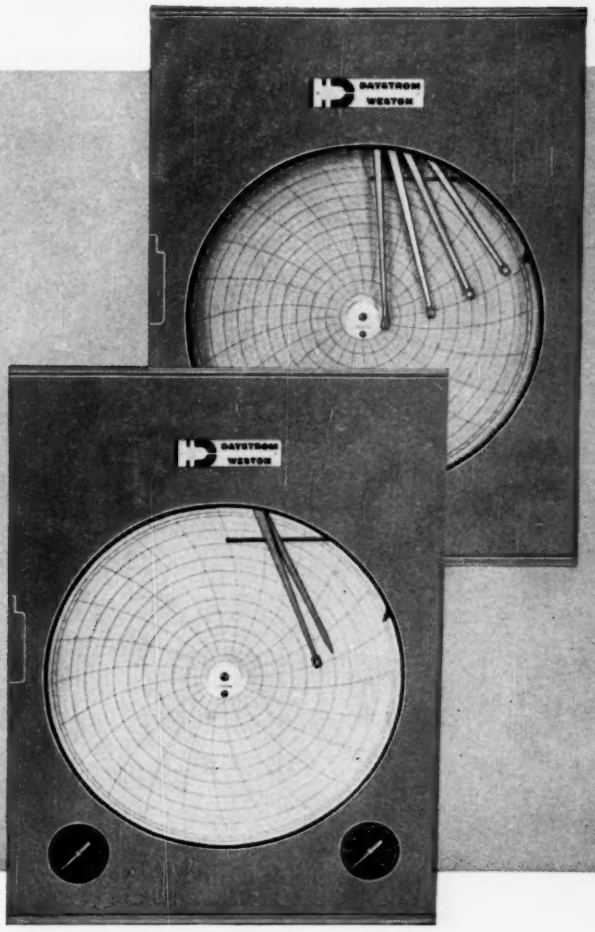
CIRCLE 178 ON READER-SERVICE CARD

Dictionary of Atomic Terminology, edited by Lore Lettenmeyer [c1959] Philosophical Library, Inc., 15 East 40 St., New York 16, N. Y., 298 p., 8¼", clothbound $6.00. A four-language cross-reference of terms used in nuclear and atomic physics and associated fields. English expressions are arranged alphabetically followed by German, French, and Italian sections. A comprehensive index insures locating terms easily.

CIRCLE 179 ON READER-SERVICE CARD

FILLED SYSTEM TEMPERATURE RECORDERS AND RECORDER-CONTROLLERS

Daystrom-Weston designs *New* VERSATILITY into these UNITIZED* temperature instruments



This new line of recorders and recorder-controllers covers the complete range of filled system instruments. Charts and ranges are available as low as −100° F. and as high as 1000° F. The series includes *Model 7811:* single pen recorder . . . *Model 7812:* multi-pen recorder *Model 7815:* single pen recorder-controller . . . *Model 7816:* two pen, two control unit . . . *Model 7817:* two pen, single control unit.

All models come in dust- and moisture-proof cases for universal mounting. Cases and internals are unusually clean in design, and provide easy accessibility. Pens have large capacities, rugged suspensions and automatic lifters. In addition, the series offers these important features:

- Interchangeable thermal systems — liquid-, vapor-, gas-, or mercury-filled.
- 12-inch charts, with 4.75-inch pen travel.
- Universal pneumatic controller may be used as a proportional . . . on-off . . . or differential gap controller.
- Proportional controller is available with reset — or reset and derivatives.
- Proportional band adjustability from 2 to 300%.
- Reset and derivative valves are adjustable from 0.02 to 5 minutes.
- Control setting and manual reset are simplified and easily accessible.

Circulars M-15-A and M-18-A contain full specifications. Contact your local Weston representative, or write to Weston Instruments, Division of Daystrom, Inc., Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.*

***UNITIZATION:** the grouping of related components— in Daystrom-Weston Industrial Instruments — in the simplest, most serviceable, most efficient manner.

DAYSTROM-WESTON

Industrial Instruments

A DAYSTROM UNIT

CIRCLE 47 ON READER-SERVICE CARD

Your *FISHER/MAN* offers you

SPEEDY DELIVERY

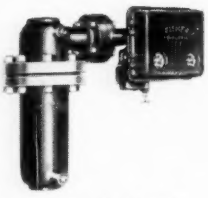
From the Factory Stocked

FISHER SUPERMARKET

Where you can shop by phone, wire or TWX

Type 657-A with 3500 positioner

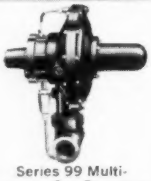
Type 4150 and 4160 Wizard II Pressure Controllers



Series 2500-249 and 2500-259B Level-Trols

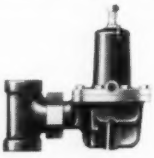
Type 95-H Pressure Reducing Valve

Type 630 "Big Joe" Field Regulator

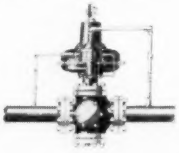


Series 99 Multi-Purpose Gas Regulators

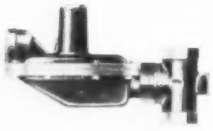
Type 655-A Pressure Regulator



Series 620 and 621 Farm Tap Regulators

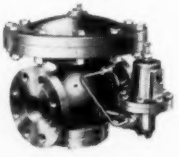


Series 298T Gas Regulators



Series S100 and 730 Service Regulators

Series 67FR Combination Filter-Regulator



Type 92B Pilot Operated Steam Reducing Valve

This "supermarket" availability of Fisher Control Valves and Controllers makes your delivery problems a thing of the past. Fisher keeps a stock of the equipment at left always on hand ready to ship to you at hourly notice. This means emergency requirements are met without costly delivery delays. This stock of control equipment includes all the most popular types in standard sizes.

In addition to the large factory stock, the Fisher offices in the column to the right which are starred carry a big selection of Fisher equipment in inventory to assist you.

Fisher constantly reviews the stock carried in the Supermarket and adds new items from time to time when your needs indicate.

Phone, wire or TWX (Marshalltown 578 or 579) and Fisher will have your order en route in a matter of hours, Saturday and Sunday excepted.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

FISHER® Controls

SINCE 1880

CIRCLE 48 ON READER-SERVICE CARD

Now, for emergency needs contact FISHER or the representatives listed below.

*AMARILLO
Vinson Supply Company
*ATLANTA
J. M. Smither & Company
BALTIMORE
The Rhodes Controls Company
BIRMINGHAM
Joseph W. Eshelman & Company
BOSTON
Clarence B. Petty & Company
BUFFALO
W. J. Sommers Company
*CALGARY-EDMONTON
Barber Engineering & Supply Company
CARACAS, VENEZUELA
Sinclair Spence
*CHARLOTTE
Robert E. Mason & Company
CHICAGO
General Meters & Controls Company
CINCINNATI
H. T. Porter Company
*CLEVELAND
A. E. Ehrke & Company
*DALLAS
Vinson Supply Company
*DENVER
Joy & Cox, Inc.
*DETROIT
DuBois-Webb Company
*HOUSTON-CORPUS CHRISTI
Puffer-Sweiven Company
INDIANAPOLIS
Acme Engineering Agency
KANSAS CITY
Sullivan-Mears Company
*LOS ANGELES
B. R. Jones & Company
LOUISVILLE
Allan K. Cook Company
MARSHALLTOWN
R. S. Stover Company
MEMPHIS–NASHVILLE
Johnson & Scott
MEXICO, D. F.
Babcock & Wilcox de Mexico
MILWAUKEE
W. D. Ehrke & Company
MINNEAPOLIS
R. G. Read & Company
MONTREAL
Process & Steam Specialties, Inc.
*NEW ORLEANS–LAFAYETTE
John H. Carter Company
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Crabbe & Stebbins Company
*ODESSA–FARMINGTON
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Cone & Wallace Company
PITTSBURGH
J. G. Chilcoat & Company
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R. H. Brown & Company
RICHMOND
W. H. Kidd Company
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H. D. Hale & Company
SALT LAKE CITY
Williams, Gritton & Wilde
*SAN FRANCISCO
George R. Friederich & Company
*SEATTLE
Power & Controls, Inc.
*SHREVEPORT
John H. Carter Company
TORONTO
George W. Beecroft & Company
*TULSA
Vinson Supply Company
VANCOUVER
Northern Columbia Process Equipment Company
*WICHITA–LIBERAL
Sullivan-Mears Company
WINNIPEG
Mechanical Valve & Engineering Spec.

IGS PANHANDLE PETE

EMPLOYMENT OPPORTUNITY

WESCO! Systems Division has an opening for a systems engineer who desires a challenging and responsible position. The Systems Division of WESCO!, like all systems firms, desires a young (not over 30 years age) and well-rounded man with both advanced degrees and 20 years of practical experience in the several fields comprising modern systems engineering.

These fields include:

A. Electronic
B. Electrical
C. Pneumatic
D. Hydraulic
E. Mechanical
F. Optical
G. Chemical
H. Nucleonic

The systems engineer must intimately know the industry for which he designs the system. These include:

A. Ferrous industry
B. Nonferrous industry
C. Chemical industry
D. Petrochemical industry
E. Power industry
F. Food industry
G. Manufacturing industry
H. Machine tool industry
I. Rubber industry
J. Nuclear industry

The functions will be those of the modern systems engineer:

A. Design of system
B. Application of components in subsystems
C. Optimum use of subsystems in integrated systems
D. Field installation and startup of new systems

The systems engineer must be facile with the following mathematical techniques:

A. Differential equations
B. Statistics
C. Complex variables
D. Analog computer techniques
E. Digital computer techniques
F. Linear programming
G. Information theory
H. Operational mathematics
I. Laplace transforms
J. Bode diagrams
K. Computer programming
L. Boolean algebra

The systems engineer must have experience with the following phases of modern electronics:

A. Transistor circuit design
B. Magnetic amplifier circuit design
C. Solid state physics
D. Moleculonics
E. Power amplifier design
F. Parametric amplifiers
G. Modularization

The systems engineer applies his skills in the following areas and must be conversant with each:

A. Transducer design and use
B. Telemetering of signals
C. Thermodynamics
D. Mechanical linkages
E. Fluid mechanics
F. Microminiaturization
G. Adaptive servomechanisms

The skills listed are all essential. The following are desirable also:

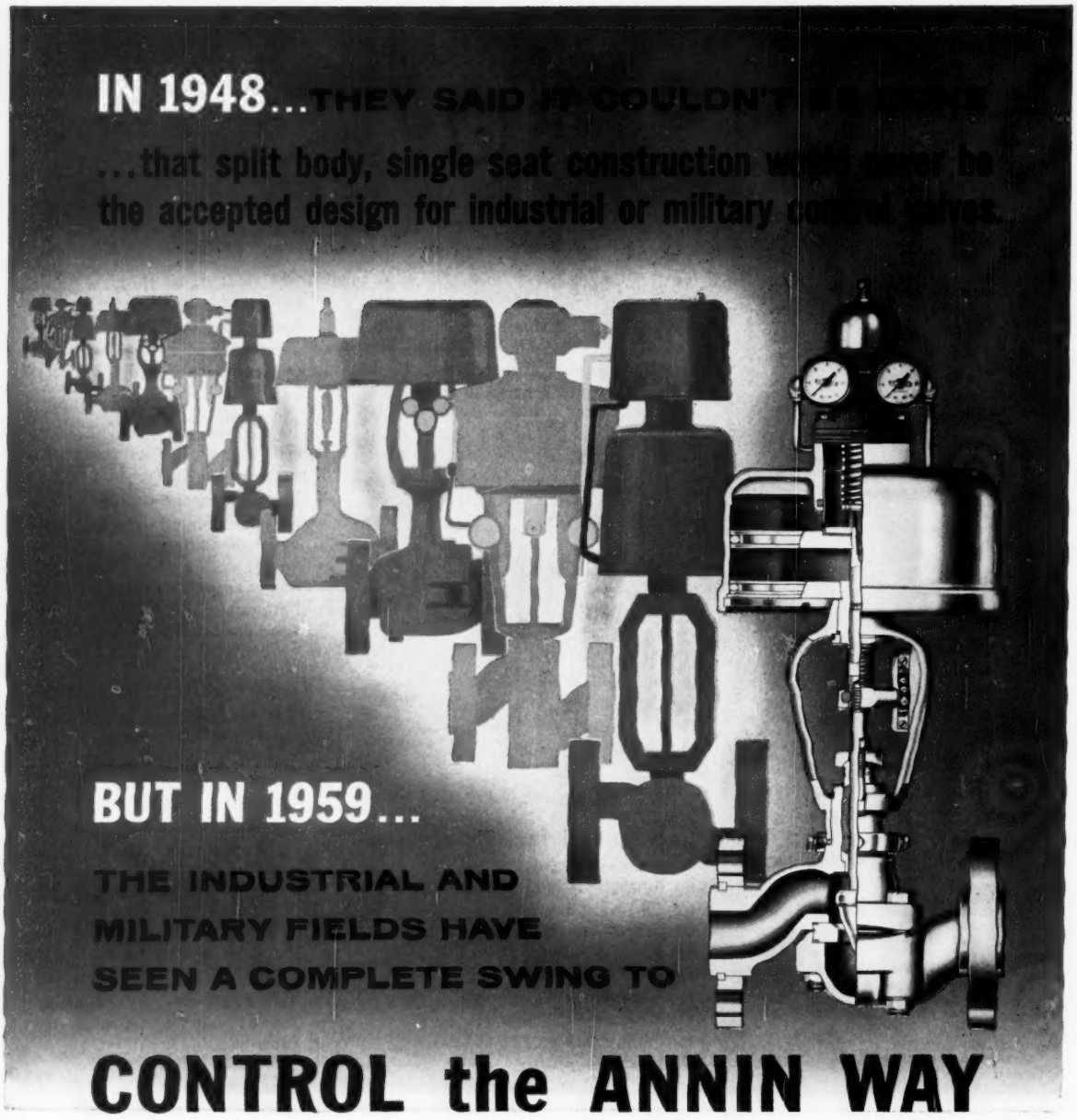
A. Writing ability in preparing reports, contracts, technical articles, etc.
B. Value engineering
C. Ability to supervise entire systems
D. Ability to work with others in a group
E. Ability to get along with others doing similar work
F. Aggressiveness
G. Willingness to take orders
H. Extraverted personality
I. Introverted abilities

He must be married, have family, own home in refined neighborhood, and be willing to relocate.

Write WESCO! personnel Div., on company letterhead typed by company secretary, giving name and private phone number of immediate superior. All information will be kept confidential.

Pay will depend on ability—up to $9000.

Panhandle Pete


IN 1948...THEY SAID IT COULDN'T
...that split body, single seat construction
the accepted design for industrial or military
BUT IN 1959...
THE INDUSTRIAL AND
MILITARY FIELDS HAVE
SEEN A COMPLETE SWING TO
CONTROL the ANNIN WAY

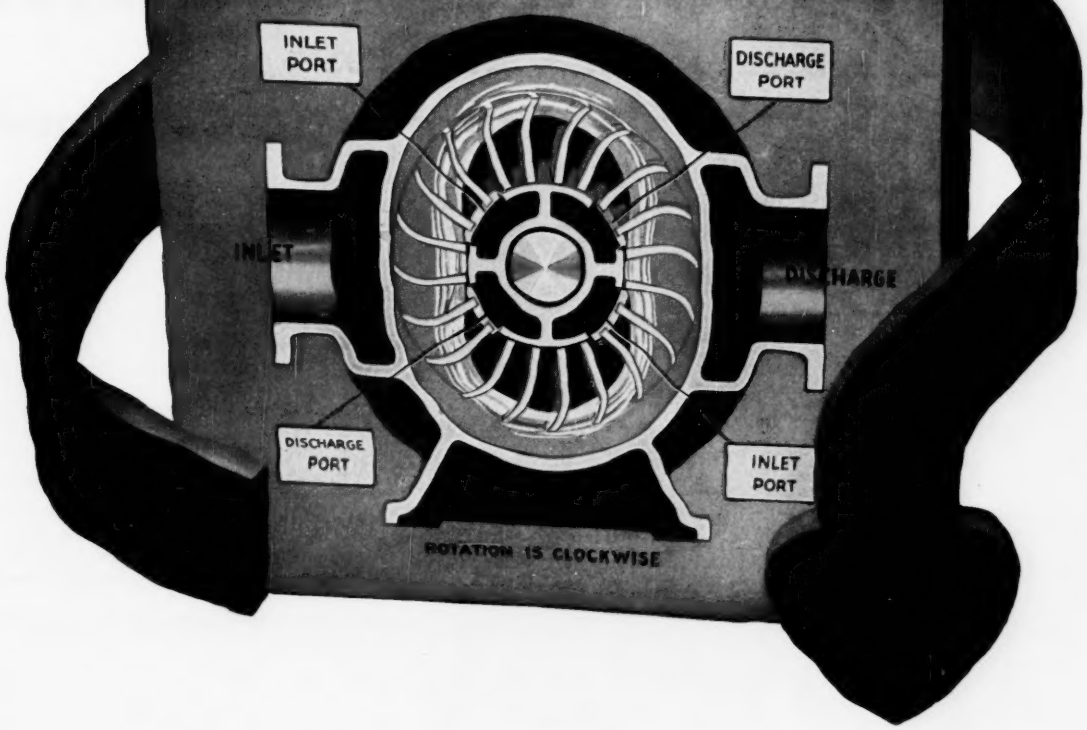
In 1948 split body construction and powerful high speed, precise positioning pneumatic piston actuators were available from only one source—Annin. Today, more than a decade of accumulated experience in this type of valve design makes Annin features and performance records the best in the valve industry. Contrary to published statements by critics ten years ago, Annin-type construction is now available from many sources. But when tempted to consider *mere-replicas* of Annin valves, remember this—they might give you a few Annin features, but when you specify Annin Valves you get them all!

Annin VALVES

THE ANNIN COMPANY
1040 South Vail Avenue
Montebello, California

CIRCLE 49 ON READER-SERVICE CARD

Nash Instrument Air Compressors deliver only clean air, free from oil or dust, and without filters



Here is Why!

You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

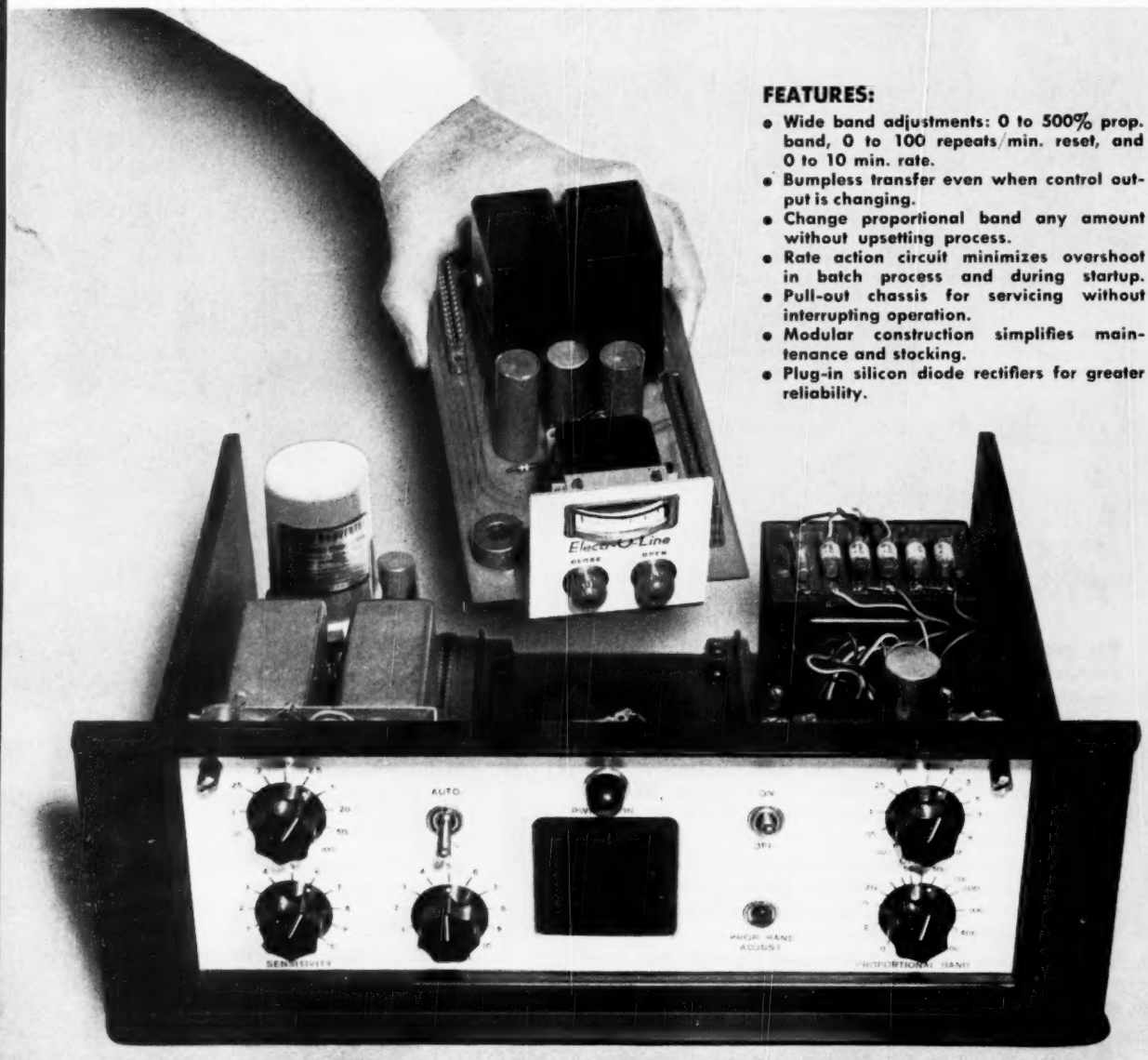
®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

No oil filters.
No dust filters.
No internal lubrication to contaminate air handled.
No internal wearing parts.
No valves, pistons, or vanes.
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY
370 WILSON, SO. NORWALK, CONN.

3 All New electric

. . . to make



FEATURES:

- Wide band adjustments: 0 to 500% prop. band, 0 to 100 repeats/min. reset, and 0 to 10 min. rate.
- Bumpless transfer even when control output is changing.
- Change proportional band any amount without upsetting process.
- Rate action circuit minimizes overshoot in batch process and during startup.
- Pull-out chassis for servicing without interrupting operation.
- Modular construction simplifies maintenance and stocking.
- Plug-in silicon diode rectifiers for greater reliability.

All three units use the same plug-in components . . . only the control output section is different. Simplifies on-the-job servicing . . . eliminates need for complicated test equipment.

3-mode control units

furnaces perform at their best

***Electr-O-Line* Control Unit**—For electronic position-proportioning control with reset and rate action

***Electr-O-Pulse* Control Unit**—For electronic time-proportioning control with reset and rate action

***Electr-O-Volt* Control Unit**—For electronic current output proportioning control with reset and rate action

One of these units—*Electr-O-Line*, *Electr-O-Pulse* or *Electr-O-Volt*—will deliver the exact kind of temperature control that's best for your furnace.

Plug-in construction is used throughout all three units—including common amplifier and power supply sections. Operator adjustments are exactly alike for all three units. Interchangeability of control output sections simplifies stocking and service problems.

Get complete details on these and other types of furnace controls from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

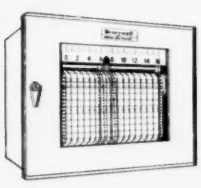
First in Control

SINCE 1885

75th YEAR

PIONEERING THE FUTURE

CIRCLE 50 ON READER-SERVICE CARD



Use *ElectroniK* strip chart, circular chart or circular scale controllers to actuate *Electr-O-Line*, *Electr-O-Pulse* or *Electr-O-Volt* units. They are integrally mounted, simplifying panel cutout and reducing wiring costs.

NEW BAILEY
Multi-Pointer Gage

...has twice as many indicators
...no taller than a telephone!

Now the popular versatile Bailey Multi-Pointer Gage has been reduced in size to conserve control panel space—without loss of easy *readability*.

Each new Multi-Pointer Gage Unit offers you these three choices to—

1. Measure and indicate draft, pressure, differential pressure and level.
2. Transmit above variables either pneumatically or electrically to remote indicators, recorders and/or controllers.
3. Receive and indicate any measured variables which may be transmitted pneumatically by standard SAMA ranges of 3-15 psig. or 3-27 psig.

FEATURES

Compact Size—Two large, easily-read 7″ scales in space only 4 inches wide.

Wide Range Selection—Standard ranges from 0-0.5 in. H_2O to 0-5000 psig available.

Choice of Standard Colors—Satin Black, Slate Gray, Moss Green, or Terra Tan may be selected as an exterior color at no additional cost.

Colored Scales—Scales available in white, red, green, blue, yellow, or orange.

Fluorescent Illumination—All gages have slideout unit containing bulb and starter for ease of maintenance.

Readily Accessible Adjustments—Zero adjustment made from front of gage. Other adjustments made from rear of gage.

Two-point Positive Mounting—Gage unit mounted with two clips . . . no holes to drill or studs to weld.

Unlimited Indications—Any number of basic two-indicator units may be placed side-by-side to provide indications of related factors. Each two-indicator unit is separatelymounted.

For additional information, call your local Bailey District Office, or write us direct. G47-1

Instruments and controls for power and process

BAILEY METER COMPANY

1041 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

CIRCLE 51 ON READER-SERVICE CARD

EVER REALLY EXPLORE INNER SPACE?

Inner space of copper Capillary and Restrictor Tubing, that is? Especially that used for instrumentation and controls? Kensico recently asked an independent consulting service to explore the inner space of its small-diameter, *precision-drawn* tubing in comparison with leading competitive products. Some mighty revealing discoveries were made by using *photomicrography!* Interested control engineers may obtain a set of these photomicrographs—or Free Flow Charts and engineering consultation—by simply calling, writing or wiring . . .

We also make hard and soft copper water tube . . . copper air conditioning and refrigeration tubes . . . copper tubing for propane gas lines, heat exchangers, automotive and industrial applications.

CAMBRIDGE, MASS. • MIDDLEBURY, CONN. • BUFFALO, N. Y. LINDENHURST, N.Y. • GOSHEN, N.Y. • ROSELLE, N.J. • PHILADELPHIA, PA. • FLOURTOWN, PA. • PITTSBURGH, PA. • CLEVELAND, OHIO DETROIT, MICH. • EVANSTON, ILL. • ST. LOUIS, MO. • MILWAUKEE, WISC. • DURHAM, N.C. • FT. LAUDERDALE, FLA. • ST. PETERSBURG, FLA.

Kensico Tube

COMPANY INCORPORATED, MT. KISCO, N. Y.

CIRCLE 52 ON READER-SERVICE CARD

HERE'S HOW YOU CAN SAVE MONEY ON PRESSURE SWITCHES FOR YOUR SPECIAL REQUIREMENTS...

For sensing pressure differences of .45 to 80 inches of water vacuum or pressure.
For extreme accuracy, single and dual setting switches in the working range of 30 inches of mercury vacuum to 100 P.S.I. pressure. Housed models.
For mounting in a common control cabinet, stripped models in the working range of 30 inches of mercury vacuum to 100 P.S.I. pressure.
For differential sensing of .05 to 100 P.S.I.
For dual setting high and low limit protection.
For widely adjustable differential and high proof pressure.
Explosion-proof models for low pressure and vacuum sensing, single and dual setting.
Models with variable actuation value.
For heavy duty, single and dual setting up to 7000 P.S.I. proof pressures.
Models with external calibration dial.
Explosion-proof models for high pressures.
For use with highly corrosive media.
For accurate sensing of high pressures, single and dual setting.
For extremely long service life, high proof at settings from 35 to 12,000 P.S.I.
For sensing high differential pressures.

If you feel that the pressure switch for your application has to be tailor-made to your requirements, we can offer you the know-how, the experience and probably considerable savings in the bargain.

The know-how is available to you in the form of an engineering and production facility entirely specialized on the design and manufacture of pressure switches. Ask to see the 20-minute sound movie, "The Meletron Story."

The experience we can offer you has been put to the test in every conceivable type of industrial pressure switch application. Ask our representative in your area to show you applications resembling your own.

The savings you can make will be apparent when you consider that there are over six hundred pressure switches listed in our catalog. Even if you should require a special pressure switch, the major components are already in production. Ask for the latest pressure switch handbook and catalog.

PRESSURE SWITCH DIVISION

Barksdale valves

5125 ALCOA AVENUE • LOS ANGELES 58 • CALIF.

THERE IS A BARKSDALE REPRESENTATIVE IN YOUR AREA:

Alabama, Birmingham	Missouri, Kansas City
Arizona, Phoenix	St. Louis
California, Los Angeles	Nebraska, Omaha
San Diego	New Jersey, Neptune
San Francisco	New York, Buffalo
Colorado, Denver	New York
Connecticut, Wethersfield	Rochester
Dist. of Columbia, Washington	Syracuse
Florida, Miami	North Carolina, Charlotte
Georgia, Atlanta	Ohio, Cincinnati
Illinois, Chicago	Cleveland
Rockford	Dayton
Indiana, Indianapolis	Oklahoma, Tulsa
Kansas, Wichita	Oregon, Portland
Kentucky, Louisville	Pennsylvania, Abington
Louisiana, New Orleans	Pittsburgh
Maryland, Baltimore	Tennessee, Memphis
Massachusetts, Newton	Texas, Houston
Michigan, Detroit	Washington, Mercer Island
Minnesota, Minneapolis	Wisconsin, Milwaukee

CIRCLE 53 ON READER-SERVICE CARD

PROJECT 70,000,000

Since their introduction more than ten years ago, CLARE Type J Relays, with their small size, twin contact design and superior performance, have been first choice of design engineers for applications where component failure is intolerable.

Sensational demand for these relays has resulted in numerous imitations. Similar in appearance and published specifications, many have been represented as "just as good" as the original CLARE Type J Relays.

An independent laboratory has just completed exhaustive tests of CLARE Type J Relays and copies made by other well known manufacturers.

The results are here. Tests of the CLARE relays were discontinued at 70,000,000 cycles . . . *with no contact failure whatsoever.* All the other relay groups showed failure of 10% of their contacts before the end of 60,000,000 cycles (see graph). Some had 22% contact failure at 5,000,000 cycles.

Let us tell you more about this important test. Call or write: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Limited, P. O. Box 134, Downsview, Ontario. Cable Address: CLARELAY.

CLARE RELAYS

FIRST in the industrial field

Independent tests* prove There are no copies "just as good" as CLARE type J RELAYS

CLARE RELAYS (8 Form C)	**70,000,000 Operations No Contact Failures**
BRAND X1 (8 Form C)	60,000,000 Operations 11 Contact Failures
BRAND X2 (8 Form C)	40,000,000 Operations 12 Contact Failures
BRAND X3 (8 Form C)	30,000,000 Operations 8 Contact Failures
BRAND X4 (8 Form C)	20,000,000 Operations 12 Contact Failures
BRAND X5 (8 Form C)	15,000,000 Operations 7 Contact Failures
BRAND X6 (8 Form C)	10,000,000 Operations 11 Contact Failures
BRAND X7 (8 Form C)	5,000,000 Operations 18 Contact Failures

*Failure of 10% of the total contacts involved eliminated any group from the test. Additional data available on request.

CIRCLE 54 ON READER-SERVICE CARD

0110 1001 1001 1000

RECOMP

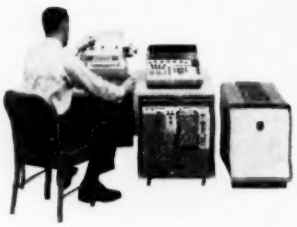
THINKS IN "BITS" BUT TALKS YOUR LANGUAGE

The binary combinations of ones and zeros stored in computers are called "bits"... and there are 160,000 of them stored in RECOMP.

RECOMP's exclusive readout panel converts these "bits" into arabic numerals... providing fast, easy readout of any word or number in the magnetic disk memory. RECOMP *communicates* in your language. Under computer control or at the push of a button, the unique readout displays in a choice of three formats: decimal, octal, or command.

The all-transistorized, general purpose RECOMP has built-in floating point and square root arithmetic... high-speed photoelectric tape reader (400 characters per second)... 4,096-word memory, including 16 words placed in high-speed loops, and a storage capacity of over 8,000 instructions.

RECOMP provides fast and accurate answers to problems of engineering, science and industry. It's available now for sale or lease... *and there's no extra equipment to buy or cost of installation.* For information on how RECOMP can solve your special problems, please write Autonetics Industrial Products, Dept. 602, 3584 Wilshire Blvd., Los Angeles 5, California.



Digital computers by Autonetics

INDUSTRIAL PRODUCTS

A DIVISION OF NORTH AMERICAN AVIATION, INC. Other offices: Chicago, New York, Washington, D.C.

U. S. PRODUCTION OF INDUSTRIAL MECHANICAL MEASURING AND CONTROLLING INSTRUMENTS

THE accompanying tables summarize the survey on U. S. production of industrial mechanical measuring and controlling instruments in 1958 conducted by the Scientific, Motion Picture, and Photographic Products Division. Detailed data on the survey, together with an analysis and interpretation, will be presented in the *Mechanical Measuring Instrument Study* now in preparation.

The third in a series of six, this study will be incorporated into the overall statistical program designed to obtain information on the nature and structure of the scientific and process-control instrument field. The *Precision Optical Components Study* and the *Electrical Measuring Instrument Study* have already been published.* A survey of nuclear instrument production is being prepared, to be followed by surveys on electric-electronic test and measuring apparatus and on laboratory instruments.

TABLE 1.—PRODUCTION OF INDUSTRIAL MECHANICAL MEASURING AND CONTROLLING INSTRUMENTS, BY TYPE, 1958

Type	Number of instruments	Value ($1,000)
Liquid-sealed (excluding manometers)	18,257	8,370
Manometers (single tube U-tube)	79,290	4,123
Variable area	179,889	9,386
Rotating member (positive displacement)	723,109	38,011
Piston vs. calibrated spring	70,778	784
Mass flow	4,955	4,081
Open float and cable	297,701	5,448
Enclosed float	77,729	5,055
Pump	9,415	6,043
Bourdon tube	5,046,451	42,415
Bellows or capsule	386,074	26,946
Diaphragm	1,882,020	25,049
Liquid- or mercury-in-glass thermometers	861,988	4,120
Bimetallic thermometers	674,887	3,749
Tachometers	1,057	279
Humidity	23,751	4,089
Miscellaneous	107,233	4,385
Total	10,444,584	192,333

*I&CS, August 1956, pages 1509-1510; October, 1958, page 1662; January, 1959, pages 71-73; January, 1960, pages 53-55.

TABLE 2.—PRODUCTION OF INDUSTRIAL MECHANICAL MEASURING AND CONTROLLING INSTRUMENTS, BY OPERATIONAL CHARACTERISTIC, 1958

Characteristic	Number of instruments	Value ($1,000)
Recording	98,194	28,834
Indicating, pointer and dial type	7,301,525	65,016
Indicating, other	1,760,123	24,559
Integrating[1]	494,587	34,345
Controlling, nonindicating nonrecording	790,155	39,579
Total	10,444,584	192,333

[1]Instruments that have only integrating features; the first three categories include 154,611 instruments having integrating as well as other features.

Following is a list of instruments incorporating controlling, transmitting or contact-making features:

	Number
Controlling:	
Pneumatic	227,461
Hydraulic	72,558
Electrical	205,584
Transmitting:	
Pneumatic	74,521
Hydraulic	978
Electrical	61,549
Contact-making: Electrical	366,104

TABLE 3.—PRODUCTION OF INDUSTRIAL MECHANICAL INSTRUMENT ACCESSORIES, 1958

Type	Number	Value ($1,000)
Primary flow elements	113,233	7,040
Thermometer wells and temperature element wells	292,142	2,868
Controllers, self operated	1,252,689	34,134
Controllers, separately mounted	86,934	14,988
Relays	12,450	585
Signal converters	145,032	4,956
Hand-automatic switches	12,491	1,387
Positioners, valve or drive	32,284	3,026
Control drives	13,455	3,805
Valve actuators	319,469	13,212
Valves—controlling or shut-off, for use with diaphragm, bellows, sylphon, or piston and cylinder operated valve actuators	974,051	65,221
Miscellaneous	16,335	1,521
Total	3,270,565	152,743

Process Control Systems

FRED D. MARTON, Instruments Publishing Company

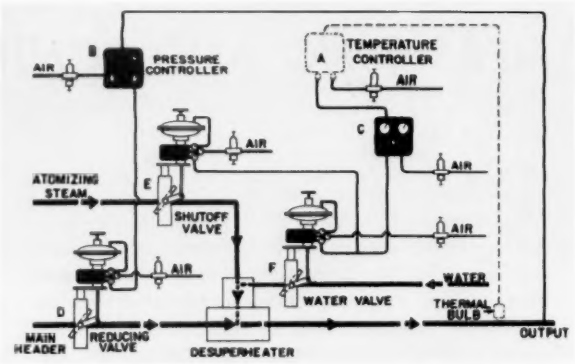
PRESSURE REDUCING AND DESUPERHEATING STATION USES BUTTERFLY VALVES

It is often necessary to take high-pressure and high-temperature steam from the main steam header and reduce pressure and temperature simultaneously so that the steam may be used for plant heating, old engines, etc. Lower pressures are usually obtained by a reducing valve. Butterfly valves offer several advantages—(1) they are suited for high pressure drops (up to 1200 psi) and temperatures to 2000°F, (2) they can pass approximately 50% more flow when 60° open than a double-seated globe valve of the same size can handle at 80% stem lift, (3) they are self cleaning, and (4) their initial cost is low.

Desuperheaters reduce the superheat by water injected into the steam line. The steam from the supply line is used as an atomizing agent to evaporate the water and reduce the superheat (temperature) of the main steam line. Desuperheaters are used also to regulate the condition of the steam leaving the steam generator because the steam sometimes becomes too highly superheated for use.

The temperature is usually controlled by a temperature controller (A). As the temperature goes below the desired point, the water to the desuperheater is reduced to raise the temperature, and vice versa. The temperature control signal is fed to the water valve via a manual-automatic panel loading station (C).

A total of three butterfly valves are required for pressure reducing and desuperheating. The largest of these valves (D) is for steam pressure reducing service and can be actuated by a diaphragm operator or



pneumatic-operated piston. Both types have positioners for accurate and reliable control.

The valve supplying steam to the desuperheater (E) has smaller size. The third valve is the water supply valve (F). The pressure-reducing valve is operated by a simple primary pressure controller (proportional control only) with the tap located downstream of the pressure reducing valve.

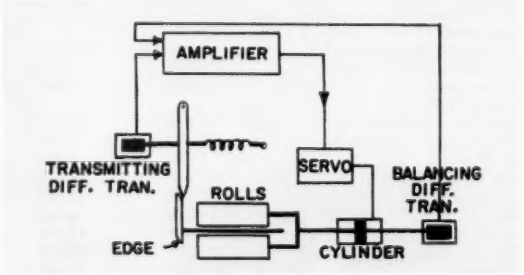
The steam supply valve (D) and the water supply valve (F) operate on a split and overlapping-range pneumatic signal, which on start-up allows the steam supply line to be open prior to the entry of water into the desuperheater.

Source: Continental Equipment Co., Div. of Fisher Governor Co., Coraopolis, Penna.

EDGE GUIDE CONTROL BY LVDT

Edge position control on web material moving at high speeds is essential for proper coiling. This simple electrohydraulic system uses a mechanical edge feeder pickup connected to a servo-controlled hydraulic system.

The fulcrum of the sensing lever is located so that the feeling edge has a 6:1 displacement ratio relative to the armature of a transmitting differential transformer. This transducer generates an a-c signal which is directly proportional to the displacement of its armature from the electrical center of the transformer winding. Motion of the armature unbalances the circuit and on output signal is fed through an electronic amplifier to the servomotor which positions a hydraulic pilot valve. A controlling piston attached by its rod to the guide rolls or reel mechanism keeps the web in register accurate within 0.001″ over a range of approximately 2″. Rate of correction varies



with the amount of error. Only ¼-oz force is exerted by the feeler on edge of web.

Equipment: Atcotran Edge Feeler unit with LVDT: Atcotran Servo unit with balancing LVDT; Amplifier: Hydraulic Cylinder.

Source: Automatic Timing & Controls, Inc., King of Prussia, Penna.; also Application Bulletin 116.

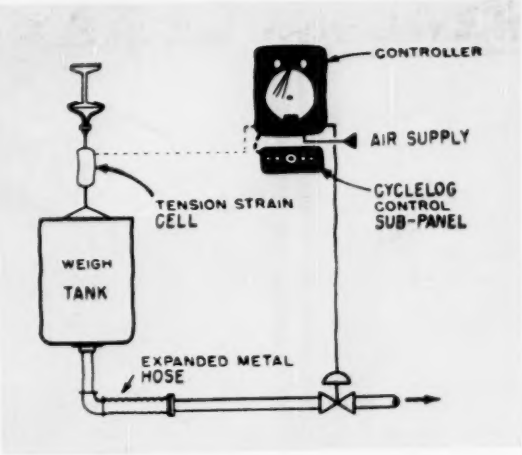
MEASURING FLOW OF UNUSUAL MATERIALS BY WEIGHT

Liquid flow of certain materials cannot be measured accurately by conventional methods because of the nature of the flowing material. Characteristics of such material may include wide viscosity change, wide density change, high temperature, or small volume.

In these cases, especially in batch operation, measuring flow by *weight* offers a good solution. In this system a weigh tank is suspended directly from a tension strain cell. Controller receives an electric signal from the load cell. The controller emits a pneumatic signal to a control valve which allows more or less volume of material to pass from the tank at a desired rate by weight.

The Controller (Foxboro Dynalog Weight Rate CycleLog Model 9120/Model 40 C-R Dynalog with a CycleLog control subpanel) has an adjustable timer which regulates the speed of a motor which, in turn, controls the motion rate of a driven index. The relation of pen to driven index governs the pneumatic output of the Weight CycleLog Controller to the control valve. A shutdown index automatically closes the control valve when the desired weight has been transferred. The recorder shows the gradually decreasing weight in the weigh tank. The Subpanel has adjustable rate setting calibrated in pounds per unit of time.

The Strain Cell is a Tension Type U-1 with output at full rating of 0 to 2 mv/v. Single strain-cell installations are preferred over multi-cell arrangements. Cells are available for gross ratings between 200 and 50,000 lb. The working range can be anything down to a quarter of the gross rating. The strain cells have an accuracy of $\pm 1/4\%$ of the rating. As the recorder is



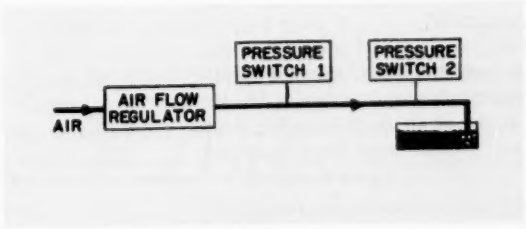
calibrated to $1/4\%$ of its span, an example shows the following combined accuracy: Assumed a 2000-lb cell is used in the span of 0 to 500. It would measure with an accuracy of $1/4\%$ of 2000 lb, or within ± 5 lb. The recorders calibration of $1/4\%$ of its range of 500 lb would furnish an accuracy of ± 1.25 lb. Thus the combined accuracy could be ± 3.75 lb to 6.25 lb, or $\pm 1\frac{1}{2}\%$ of the weight of the material. Strain cells have a hysteresis of $\pm 1/5\%$ of the change in load. Repeatability, therefore, is high.

The control valve must be selected to suit the process.

Source: The Foxboro Company, Foxboro, Mass.; also Application Engineering Data Sheet 281-17.

LIQUID LEVEL CONTROL BY "BUBBLTROL"

Basic liquid level control instruments include floats, electrical probes, pressure switches, and air purge or bubbler systems. Autocon (Automatic Control Co.) developed the first industrial "Bubbltrol" air-bubbling system in 1935; the idea quickly became popular. The "Bubbltrol" system uses an air-flow regulator which forces a constant flow *rate* of purge air through the dip tube, independent of the air supply pressure.



Hence the pressure in the tube is a function of level in the tank. Response is rapid and level can be measured to a fraction of an inch. Turbulence has little effect on the operation; tube can be remote from indicator or control, and can be slipped into very inaccessible locations; device is isolated from the medium by the air purge.

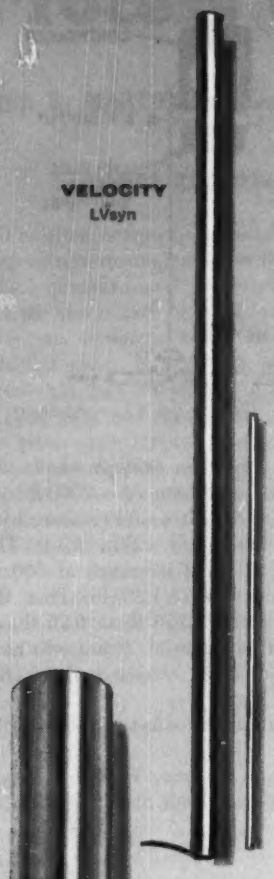
These advantages have lead to extensive use of this technique, as shown by the table. Use of several pressure switches as shown, permits operation of pumps, etc., at different levels.

Source: Automatic Control Co., St. Paul, Minn.

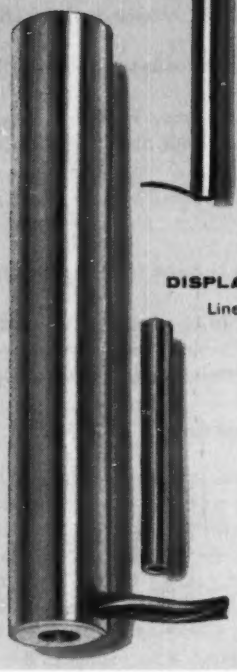
LIQUIDS TO BE CONTROLLED	TYPE OF CONTROL PRESSURE switches	Pressure-level combinations	Floats	Probes	Bubbler system
Liquids under pressure	X			X	
Liquids at high temperatures	X	X	X	X	X
Corrosive liquids			X	X	X
Explosive liquids	X	X	X		X
Radioactive liquids				X	X
Viscous liquids					X
Liquids containing solids					X
Liquids in elevated tanks	X		X	X	X
Liquids in underground reservoirs	X		X	X	X
Liquids in other inaccessible locations.				X	X
Liquids requiring proportional measurement	X		X		X
Surge and Hydro-Pneumatic Tanks		X			

DISPLACEMENT
Models 580 (top)
and 581 (bottom)

VELOCITY
LVsyn



DISPLACEMENT
Linearsyn



Precision Transducers

FROM

SANBORN

Linear motion transducers available from Sanborn Company now include the compact, ready-to-use flange-mounted *Model 580* and threaded *581* "probe-styles" for displacements as small as 0.00002" . . . thirty models (shielded and unshielded) of the rugged *Linearsyn* differential transformer for strokes from ±0.005" to ±1.0", displacements as small as 0.000001" . . . and twelve models of the *LVsyn* for producing a DC voltage proportional to a linear velocity. Features of the *580—581* probe-style units include 0.5% linearity; basic sensitivity at 2400 cps of 2.4 volts output / inch displacement / volt excitation; built-in output level adjustment, phase shift and temperature change compensation; carbide-tipped stainless steel contact rod riding in jeweled bearings. Both the *LVsyn* and *Linearsyn* transducers are extremely durable units, immersible in working fluids, introduce little or no friction, and have infinite resolution. Standard Linearsyn coil lengths range from 0.564" to 6.88", LVsyn coil lengths from 3.16" to 22.75".

For differential and single-ended pressure measurements, *Series 267 and 268* transducers for operation in a carrier system offer sensitivities of 40 uv/mm Hg / volt excitation and 40 uv / 0.1 mm Hg / volt excitation. Compact, Monel cases have standard Luer connectors.

PRESSURE
Series 267, 268

Contact your local Sanborn Sales-Engineering Representative for bulletins containing complete facts or write the Sanborn Industrial Division in Waltham. Sanborn Sales-Engineering Representatives are located in principal cities throughout the U. S., Canada and foreign countries.

for long stroke, high pressure, high temperature requirements . . .

. . . special-order LVsyn and Linearsyn displacement transducers can be supplied. Strokes up to 20" are possible . . . pressure ratings up to 5000 psi, when transducer is submerged in a high pressure medium . . . operating temperature ranges as wide as −65°F to +450°F. Consult factory, stating your requirements.

SANBORN COMPANY

INDUSTRIAL DIVISION

175 Wyman St., Waltham 54, Mass.

CIRCLE 55 ON READER-SERVICE CARD

NO STUFFING BOX OR SHAFT SEALS TO LEAK, CONTAMINATE OR REQUIRE MAINTENANCE!

VANTON

ALL-PURPOSE TEFLON* SEALLESS PUMP

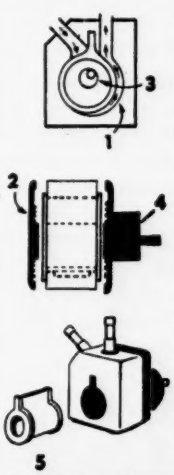
WITH KEL-F† ELASTOMER LINER

An all-purpose pump to solve problems of pumping corrosive fluids, abrasive slurries or gases in the laboratory or pilot plant. The transferred fluid is isolated to contact only with the new totally resistant fluorocarbon materials. Flow takes place on the outer surface of a Kel-F† elastomer liner and the inner surface of the Teflon pump housing. The Vanton pump is self priming and by unique design eliminates sources of difficulty such as stuffing boxes, shaft seals, gaskets and check valves. Maintenance is limited to the infrequent, 60 second replacement of the flexible liner.

Pump is available in 1 gpm, 2 gpm and 5 gpm sizes—close coupled to a ¼ HP 115/230 volt, single phase, 60 cycle, 1750 RPM, Totally Enclosed Fan Cooled, Capacitor Start motor complete with 10 ft. of extension cord with plug, base and carrying handle.

**TEFLON—Reg. trade-mark of Du Pont for its tetrafluoroethylene resin.*
†KEL-F—Reg. trade-mark of Minnesota Mining & Mfg. Co.

HOW VANTON DESIGN WORKS



Liquid flows in channel between molded Teflon body and Kel-F flex-i-liner **(1)** • No liquid touches metal • Liner flanges secured to plastic body by bolted face plates **(2)** • Pumping mechanism is rotor mounted on eccentric shaft **(3)** • At each revolution it pushes liner against body block and sweeps a slug of liquid around the circular track from inlet to outlet • All bearings are outside of fluid area, and located within a protective stainless steel assembly in the event of flex-i-liner failure **(4)** • Liners are replaced in minutes, with pump in process line, by simply removing face bolts and face plate, slipping old liner out, new one in **(5)**.

Model No.	Capacity	Discharge Pressure Range	Price Complete Teflon Housing Kel-F Liner
20741	5 GPM	0-40 psi	295.00
	2 GPM	0-30 psi	280.00
	1 GPM	0-25 psi	275.00

The EMIL GREINER Co.

20-26 N. MOORE ST., DEPT. 423, NEW YORK 13, N. Y.

CIRCLE 56 ON READER-SERVICE CARD

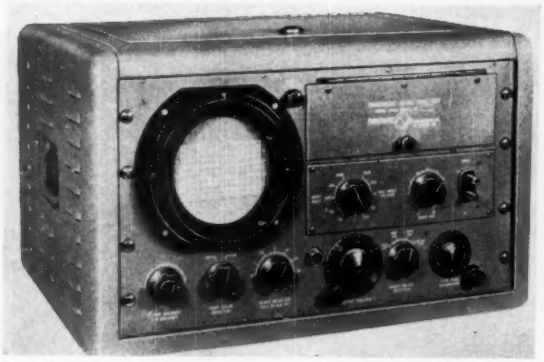


FIG. 1. PANORAMIC SONIC ANALYZER, Model LP-1a, displays amplitudes of frequency components from 40 cps to 20 kc. Frequency scale can be spread out by using linear sweep widths of ± 100, ±500, ±2500 cps about any center frequency from 0 to 20 kc. Left-hand scale shows amplitude in db; right-hand scale shows amplitude in mv.

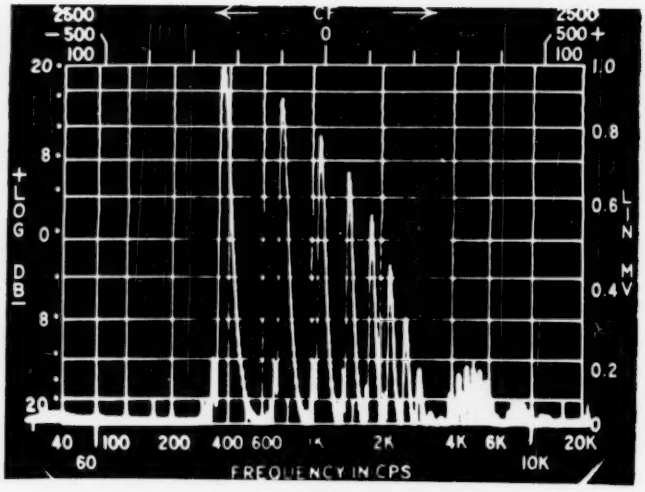


FIG. 2. SPECTRUM ANALYSIS of periodic pulse wave on 40-cps to 20-kc log frequency and linear amplitude scales. Fundamental frequency is 380 cps. For more detailed study of the low-level frequency components above 4 kc, the magnified linear sweeps of the analyzer can be employed.

Vibration Spectrum Analysis

EDWARD F. FELDMAN
Panoramic Radio Products, Inc.

AN INSTRUMENT which analyzes the vibration waveform as a function of frequency and measures the corresponding amplitude levels is indispensable for correlation of test data with specific causes of vibration. Such an instrument is used to reveal the spectral locations and magnitudes of discrete vibration frequency components. These "pitched energies" are determined frequently by rotational speeds and harmonics, gear ratios, induced structural resonances, etc. In addition, random or unpitched energy concentrations may show up as continuous distributions in specific spectrum segments. These non-discrete vibrations can be attributed to shock excitations and other transient forces. Also, friction between bearing surfaces and turbulent fluid flow often cause randomly fluctuating vibration.

Spectrum Analysis

An automatically-scanning audio-frequency spectrum analyzer is used widely in vibration tests. One such instrument (Fig. 1) presents an amplitude-vs-frequency plot of audio-frequency energy on a 5" long-persistence cathode-ray tube. The display is calibrated logarithmically along the frequency axis for the more than 9 octaves from 40 cps to 20 kc, and linearly from 20 cps to 22.5 kc; the amplitude scales also are linear and logarithmic.

The analyzer is essentially a direct-reading tuned voltmeter which repeatedly scans a prescribed band. By reference to the front-panel multiplier settings, each discrete dip can be interpreted as an rms amplitude level at its frequency abscissa. When the decibel amplitude scale is selected, the pip heights are read as db-down or db-above the 0-db level near half-scale vertical deflection. This 0-db level corresponds to full-scale linear amplitude. Thus a pip which falls at +20 db is ten times as great in voltage (100 times in power) as one with ordinate at 0 db. The db calibrations provide a ±100-to-1 visual range.

Fig. 2 shows frequency components due to a repetitive rectangular-pulse. Sweep time is one second. The non-varying nature of the signal results in an easily interpreted display which repeats identically on each sweep. The frequency and amplitude of each discrete frequency component can be seen.

Time-varying Data

Visual presentation of a spectrum facilitates rapid appreciation of the nature of a vibration waveform. Where time affects some components due to hunting, critically-excited resonances, etc., the magnitudes and

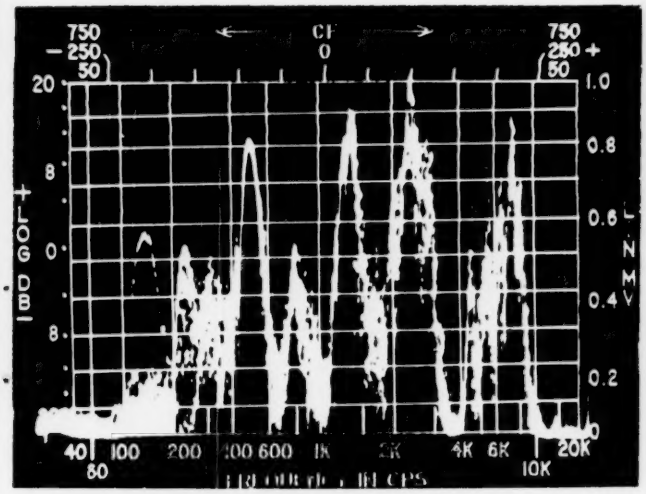


FIG. 3. GYRO MOTOR vibration at constant speed on 40-cps to 20-kc log sweep and db amplitude scales; 150-cps transient appeared once during 15 scan intervals.

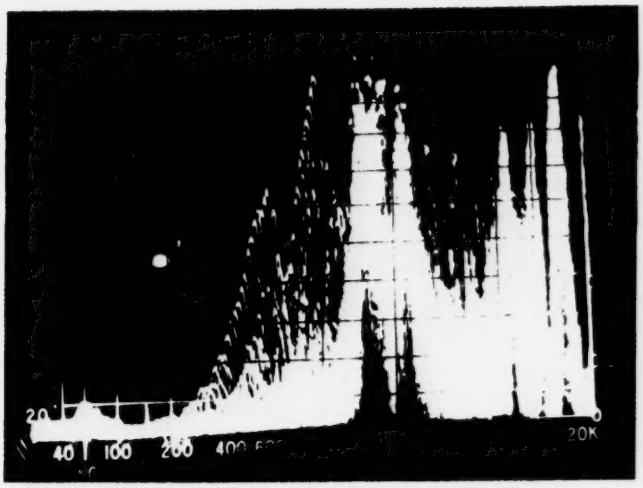


FIG. 4. COAST-DOWN test of gyro motor vibration (log-log); 60 successive scans show the precision of fundamental rotational frequency components and the resonant rise in the speed near 600 cps.

Most vibration waveforms encountered in practice have several frequency components. Thus the rms level of a signal (such as indicated on broad-band vibration meter) yields little information about the basic nature of the phenomenon under test. Such data is obtained from the spectrum analyzer.

directions of these changes can be observed by comparing repeated scans. The high-persistence screen helps compare successive displays, which also can be photographed.

Fig. 3 shows a film exposed for 15 seconds (15 sweeps) while vibration at the housing of a gyro motor was sensed with a barium-titanate accelerometer. Here both frequency and amplitude scales are logarithmic. The vibration consists of many components which repeat fairly consistently with time. However, at approximately 150 cps (a frequency considerably below the rotational speed) one discrete resonance occurred intermittently and was intercepted during one scan. The design engineer suspected this "wow" but could not measure it conveniently until the sonic analyzer was employed.

An essentially inertialess indicator is imperative for study of short-term transients. A fair degree of selectivity also was required to separate the 150-cps component from a complex noisy background. The analyzer shown in Fig. 2 has a 10-cps resolution capability.

Fig. 4 shows a coast-down analysis of another gyro motor. The photograph was taken over 60 successive sweeps. As the speed decreased, the fundamental component exhibited a generally reduced amplitude until speed approached 600 cps. Here a resonant rise can be seen, then a fairly rapid decay with further decrease in speed. Some components persisted almost independent of speed while some, particularly in the 3-6-kc region, diminished soon after the excitation was removed.

Coast-down and run-up tests of rotating devices offer excellent opportunity to study the induced resonances of a structure under operating conditions other than equilibrium. Preliminary analysis on such tests can be with the broad-band log scan.

Comparison Techniques

Insertion of frequency markers from a signal generator can improve the precision of both frequency and amplitude measurements. An electronically controlled relay switch (accessory) can be used to display two channels of information, on successive sweeps, using the high persistence of the cathode-ray-tube indicator to compare coordinates of markers and frequencies of interest. Frequency magnification permits such measurements to within a few cps, including precise comparison of two signals.

Use with Shake Tables

Automatic spectrum analysis in connection with tests using vibration tables yields important data about both the forcing and output functions. In sine-wave testing, high-g shakers often develop harmonic distortions of sufficient magnitudes to create signifi-

cant discrepancies between rms output and the fundamental-frequency amplitude. Unless a measure of each frequency component is obtained, an improper interpretation of a test result is possible.

For example, assume that a structure is to be tested at 400 cps to determine the maximum acceleration tolerable before specified failure occurs. At an overall g level of 40, the second harmonic might typically be 10% of the fundamental amplitude due to nonlinearity in the shaker armature motion. The contribution of the second harmonic, neglecting all higher modes as insignificant, is found from:

$$(40)^2 = (g_1)^2 + (0.1\ g_1)^2$$

where g_1 is the fundamental acceleration.

$$g_1 = 40/\sqrt{1.01} = 39.8$$

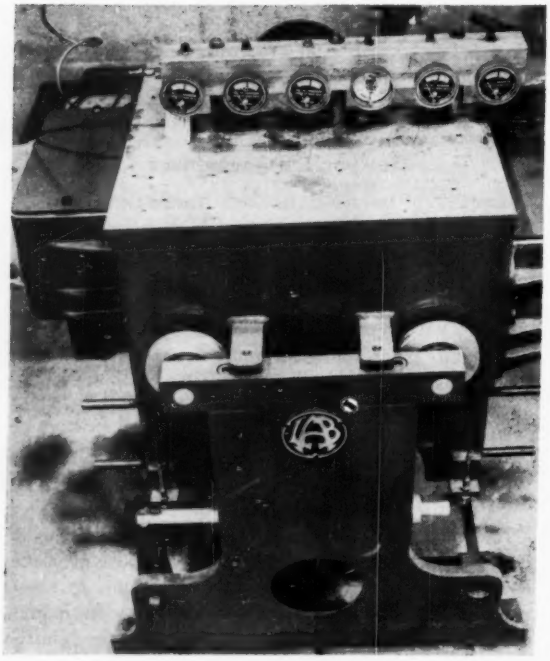
It is obvious that the 10% distortion has negligible effect on the rms forcing-function amplitude. However, the tested structure may exhibit a greater transmission at 800 cps than at the 400-cps fundamental. This can be due to the dimensions and mass distribution of the tested device, and also can be affected by reflected impedances from the shaker in an unequalized system. With a slope of 20 db per octave, or ten times amplitude, the output harmonic would be approximately equal in magnitude to the fundamental. A broad-band rms-sensitive meter would read approximately $(39.8)\ (\sqrt{2}) = 56$ g's, assuming unit transmission at the fundamental frequency and negligible high harmonics. A peak-sensitive indication would read 79.6 g's. These results would not be descriptive of the actual structural motion and could be misinterpreted for a resonance at 400 cps when the resonance is actually at 800 cps.

Use with Random-Vibration Tester

Random-vibration test systems require pre-adjustment of a series of wave filters to obtain approximately uniform (or specific pre-shaped) acceleration at the driving point of the unit under test as a function of frequency. A slave sweep-frequency generator and a spectrum analyzer have been incorporated in the control consoles of some random-exciter systems. The sweeper-analyzer combination displays the complete transfer function as a single-line trace, facilitating rapid filter equalizer adjustment.

VIBRATION TESTING OF INSTRUMENTS

WILLIAM D. HUSTON
Rochester Manufacturing Co., Inc.



OUR PRODUCTS include pressure, temperature, ampere, and fuel level gauges for farm equipment and industrial tractors, highway equipment, air compressors, truck tractors, locomotives, ships and harvesters, jet aircraft, missile and missile test stands.

Although the end uses of our instruments range from missiles to oil burners, there is a common environmental factor for all—vibration. In order to determine the effect of vibration on tractor and bulldozer instruments, we developed a vibrator built to the specifications of a group of tractor manufacturers. The machine did not prove to be satisfactory—operational and service expenses were high and it created excessive floor vibration. We eventually replaced the equipment with a commercial reaction vibration machine (Fig. 1) made by L.A.B. Corporation.

Our vibration testing procedures have three basic tests. In one test the reaction machine is set up to vibrate at a fixed amplitude but over a range of frequencies from 0 to 100 cycles per second. Equipment tested is set up to be vibrated in three different planes. We found that some are sensitive to a particular frequency within a given range.

Our second procedure is a test with fixed frequency and amplitude. This endurance test is often run for periods of 100, 500, or 1,000 hours. This is called a vibration test at resonance, where the parts or components in the product have critical frequencies where vibration effects performance.

Our third procedure is a vibration error test. In this test we look for a change in the performance of the instrument rather than an indication of the life of the instrument under severe vibratory conditions.

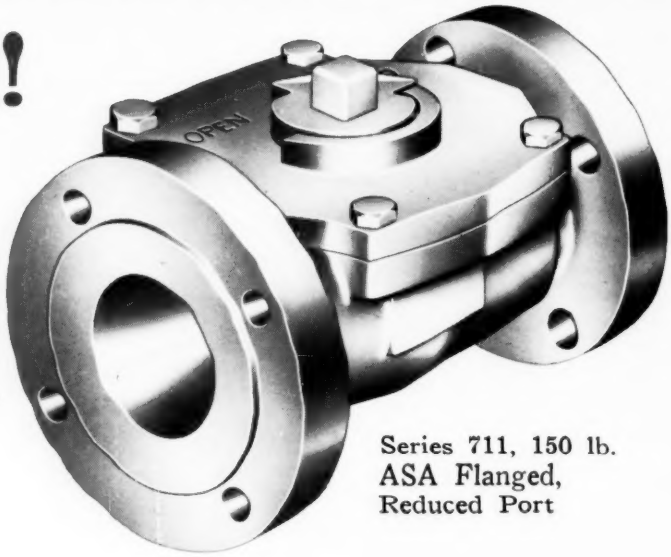
CIRCLE 57 ON READER-SERVICE CARD ⟶

totally
new!

Only *FLO·BALL* valves are bearing-fixed for maintenance-free long life!

. . . with all the features you must have:

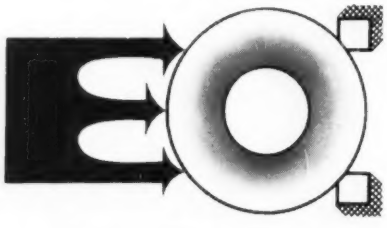
- **Top loading**
- **Replaceable seats**
- **One-piece ball and stem**
- **90° on-off**
- **Two-way flow**



Series 711, 150 lb.
ASA Flanged,
Reduced Port

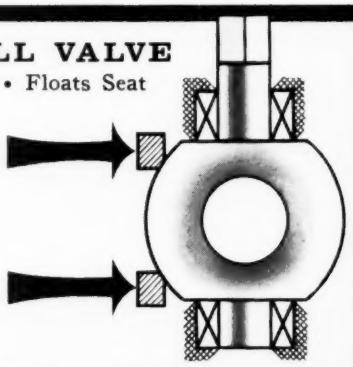
Now available . . . the result of years of intensive service in the missile-space industry . . . proven in thousands of adverse applications . . . now at mass produced prices . . . the most advanced line of ball valves ever manufactured . . . for you!

ORDINARY BALL VALVE
Floats Ball • Fixes Seat



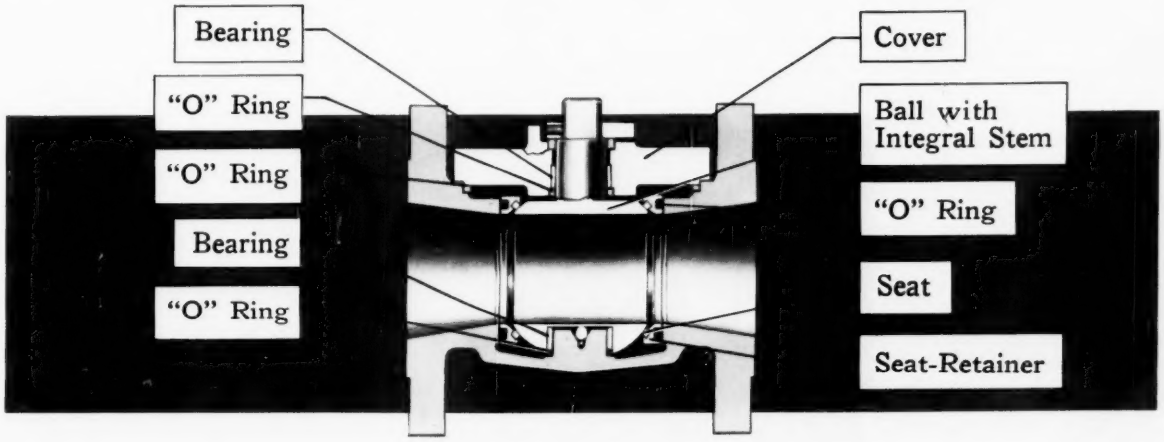
Floating ball puts excessive pressure load on fixed seats. Results in distortion and short life.

FLO • BALL VALVE
Fixes Ball • Floats Seat



FLO·BALL bearings absorb all pressure forces. Elimination of excessive seat loading insures long life.

The Series 711 ***FLO·BALL*** valves are available for off-the-shelf delivery. All are manufactured to standard ASA dimensions in semi-steel, carbon steel, 316 stainless steel, and aluminum (ASTM 356-T-6) for body and ball, Teflon for seats, and Buna "N" O-Ring seals. Other materials are also available. These valves operate at pressures to 300 psi, temperatures to 400° F.



The Hydromatics Series 711 FLO•BALL valve gives you the features you must have!

- Bearing-Fixed ball. Engineered to withstand shock and impact without distortion or backlash.
- Top loading. Valve can be disassembled and assembled without removing it from line. No special tools are required.
- Self adjusting, replaceable seats. Both balanced seats are self-aligning and self-adjusting for controlled seat loading and positive seal.
- No lubrication. Operates completely without lubrication.
- Zero leakage. At all operating pressures, including vacuum to 10^{-6} mm. of Hg.
- One-piece stem and ball. Simplified construction adds strength, precision and lower torque.
- Maximum flow efficiency. The open ***FLO·BALL*** valve provides an unrestricted, straight-thru fluid path.
- Lowest torque. Bearing-Fixed construction results in effortless, fast-action with low torque.
- Two-way flow. Exclusive ***FLO·BALL*** seat design principle insures perfect seal in both directions.

Hydromatics, Inc.

FLO· BALL

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Tear Along This Edge

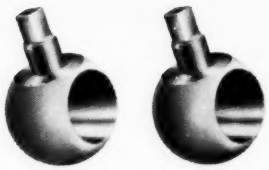
Gentlemen:
Your Bearing Fixed Flo•Ball valves from ⅛" to 24" may help solve a problem relating to the control of:

☐ Corrosive Liquids ☐ Cryogenic Liquids ☐ Throttling Flow
☐ Vacuum ☐ High Pressure

My flow problem is_____

PLEASE: ☐ Have salesman call ☐ Send technical data

My name_____ Position_____
Company name_____
Address_____
City_____ State_____



New

Maximum flow

Top loading

New

No lubrication

One piece ball and stem

New

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Displacement Transducer

FIG. 1. METRISITE displacement-sensitive transducer.

NEW displacement-sensitive Metrisite* transducer has only one moving part—an extremely lightweight armature suspended in an air-gap of a laminated magnetic structure. Movement of this armature from center produces an imbalance in flux distribution in direct proportion to the displacement. The difference in voltage of the two secondary circuits resulting from this imbalance constitutes a highly stable a-c output.

Because the armature has low mass and is nonmagnetic, energy needed to move it is slight and reaction on the mechanical input is negligible. Excellent resolution at null-point, mid-range and full-scale eliminates problems of "hunting" close to the null, or signal decay at extreme range.

The Metrisite principle adapts readily to a variety of configurations from the minute to sizes capable of measuring a motion travel of 4" or more. Units also are in production to measure angular or purely linear movements.

Production models have a proven linearity of 0.1%. Zero stability is exceptional, with repeatable response to displacements as minute as 0.0001". Resolution is limited only by the mechanical structure with which it is used.

A typical Metrisite transducer currently used in a well-known industrial control has an output of approximately 1 volt across a 330-ohm load in response to a movement of 0.2". Special units can be made with outputs as high as 100 volts. This relatively high output combined with a low background noise level greatly simplifies design of associated equipment. For example, a sensitive rectifier type meter can be operated directly *without* an amplifier.

Operated on a 60-cycle line, full-scale operation of a suitable meter is obtained from movements as small as 0.005". With suitable amplification full-scale response may be obtained from displacements of 1 microinch. Designs have proven practical well above the audio range.

*Registered tradename Brush Instruments Div., Clevite Corp.

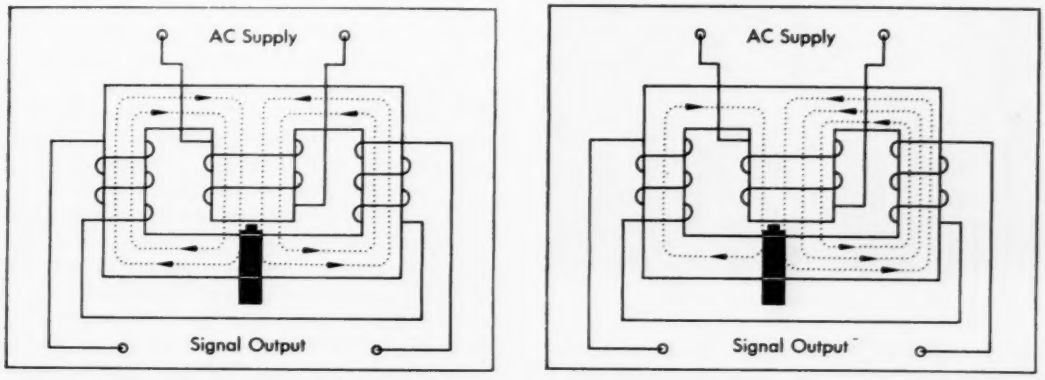


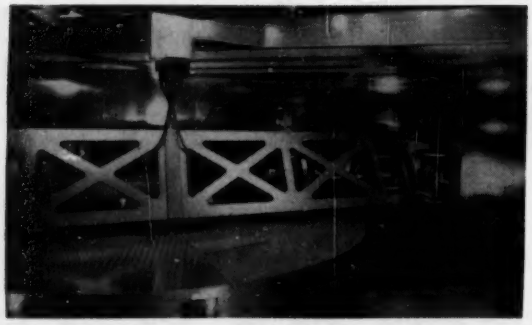
FIG. 2 PRINCIPLE of operation. Left shows flux pattern with armature centered; right shows pattern with armature off-center.

ACCELERATION GENERATORS

Five methods are used to develop an acceleration for testing equipments and for calibrating accelerometers—falling weights, shakers, oscillating tables, centrifuges, and pneumatic impulses. Here is a survey of commercial equipments.

ALVIN B. KAUFMAN
Litton Industries

A



B

C D

FIG. 1. GENISCO centrifuges include a 100"-radius-arm precision unit accurate to ±0.0005" (A). Arm has rotatable housing on end (B). C is production-line unit; D is rate-of-turn table.

FIVE METHODS are being used to develop an acceleration for driving and calibrating accelerometers and for testing equipment—falling weights, shakers, oscillating tables, centrifuges, and pneumatic impulses.

The falling weight, including the pendulum, develops an accurate velocity that is dissipated on impact, with a resulting acceleration transient.

Shakers move an object back and forth linearly, resulting in an acceleration that reverses its direction periodically. When amplitude is constant, this periodic acceleration peak is proportional to the square of the oscillation frequency.

Centrifuges usually rotate at constant angular velocity and hence provide a constant *centripetal acceleration* (directed toward the center of rotation), which can be of a large magnitude. This acceleration value can be calibrated to a high degree of accuracy.

According to Newton's second law, the acceleration toward the axis necessary to keep a particle moving in a circle about that axis is v^2/r, where v is instantaneous linear velocity. Hence the centrifugal force (due to this centripetal acceleration) is ma, or mv^2/r, or $(w/g)(v^2/r)$, or $w\pi^2N^2r/900g$ (where N is rpm).

Centrifuges

Centrifuges are used for the calibration of absolute accelerometers and for static acceleration tests of equipment. They are capable of high accuracy, but may produce gross errors unless used properly.[1]

Genisco

Figs 1A and B show a Genisco centrifuge that develops a centripetal acceleration (sometimes referred to as a gravity field) with an rms error less than ±0.001%. Strain and temperature compensation are built into the moving member. Also, environmental temperature is controlled so that the radius of gyration is accurate to ±0.0005". One end of the 100"-radius arm can take a 400-lb load to 25 g.

This precision centrifuge was designed originally to calibrate an accelerometer. The articulated housing at the precision end can be positioned at any attitude in two degrees of freedom, and is particularly useful in certain tests where zero lateral forces are desired, and also in determining the exact C. G. of the seismic mass prior to applying acceleration forces. The latter is accomplished by spining the housing with the accelerometer positioned so that zero output is obtained.

Smaller centrifuges (12″, 24″ and 38″ radii) from Genisco can provide up to 10,000 g-lb (40-lb load to 250 g). Model A-1030 has a 96″ arm, will take an 18″ cube, 100-lb weight to 175 g.

A small centrifuge developed for production-line acceleration testing is shown in Fig. 1C. Range is from 1 to 800 g with capacity of 1000 g-lb.

A rate-of-turn table (a table that features precise and controlled low and high rotational speeds) is often used for calibrating rate gyroscopes; it also can be used as a precise centrifuge for low-g testing. Fig. 1D shows a Genisco rate-of-turn table, featuring infinitely variable rate of turn from 0.01 to 1200 degrees/second, and a capacity of 100 pounds dead weight.

The driving element on the newer units is a Rouverol transmission ball-disc type with low wow and drift.

Most common applications of the centrifuges are for calibration of acceleration-sensitive devices and in acceleration testing. The acceleration, being a function of speed of rotation and radius of gyration, is measured accurately—the speed by a 600-tooth pulse generator attached to the main shaft and monitored by an electronic counter.

Schaevitz

Standard rotary accelerators manufactured by Schaevitz Machine Works include eleven models, ranging from 3- to 500-lb capacity and to 1000 g.

Model C-1-A has a nominal radius of 9″ and develops up to 250 g. It takes test objects to 3 lb. Size limit is a 5″ cube. Speed is continuously variable from 0-1000 rpm.

Largest standard accelerator is the T-16-A (Fig. 2) with 500-lb capacity at 100 g on each end of a 5′6″ nominal radius arm. Maximum size of test objects is a 5′ cube; 50 slip rings are provided; optical system for continuous observation of test object is available.

The drive mechanism is a-c to d-c electronic drive, which has good long-term speed stability with tachometer feedback. However, variable-frequency synchronous drives or ball-disc integrator drives are more suitable for the slow speeds required for programming rate gyros.

Angular velocity is measured by an rpm pickup (600 pulses per revolution) and an electronic counter. A tachometer generator can be used if 1% accuracy is sufficient; a stroboscope for instantaneous readings.

Statham

Statham RA-1 centrifugal-table acceleration generator provides up to 500 g at 1725 rpm. Model RA-2 (Fig. 3) provides 1000 g at 1940 rpm and 9″ radius within a controlled environment that can be varied from −90°F to +350°F. Rotation can be monitored to ±0.1%. Model 2B utilizes a 1-hp 120-vdc shunt-wound direct-coupled motor to spin a 20″ diameter table at useable rates between 100 and 1940 rpm. With a 9″ maximum effective radius, the table will accommodate a 5-lb test unit occupying up to a 4-square-inch table area. Rotation is controlled through the magnetic amplifier supply system; it may be accurately monitored to 0.1% using an electronic counter. Environmental conditioning permits ±4°F operation of the spin table at temperatures down to −90°F using liquid CO_2 as the coolant, and at elevated temperatures up to +350°F employing the self-contained heating system. Sixteen slip rings provide for test-unit operational connections.

FIG. 2. SCHAEVITZ T-16-A.

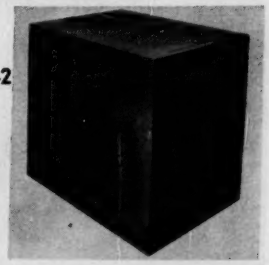


FIG. 3. STATHAM RA-2 centrifuge.

Shake Tables

Shake tables provide a quick way to determine if a finished assembly will develop troublesome resonances and component failure in service.

Shakers run all the way from small crystal-driven units to giant electrodynamic, tilting oscillators and reciprocal inertia devices that develop thrusts of thousands of g-lbs. Frequency usually is set by the operator.

Cam or reciprocal inertia shakers are generally used for package and shock-mount evaluation; electrodynamic and crystal shakers are used for accelerometer calibration or equipment evaluation with complex-wave vibration.[2]

All American Tool

The All American Tool & Mfg. Co. makes table shakers for vertical and horizontal motion with capacities of 10, 25, 100, and 150 lbs, all ratings based on a maximum acceleration of 10 g. Double amplitude is infinitely adjustable from 0″ to 0.200″ in some models and from 0″ to 0.125″ in all others. Frequency is variable from 10 to 60 cps, or from 5 to 100 cps, in all models.

These machines are direct drive in which the table (9¼″ x 9¼″ to 21″ x 18″) is oscillated by means of a matched pair of eccentrics which are infinitely adjustable from the outside of the machine (without tools) to provide any table displacement within the limits of the machine.

Frequency can be manually controlled in order to locate resonant frequencies or can be automatically cycled over the entire range of the machine, or over any segment of it.

FIG. 4. ALL AMERICAN TOOL shake table can be programmed.

FIG. 5. GENISCO-SAVAGE Model V1001 system.

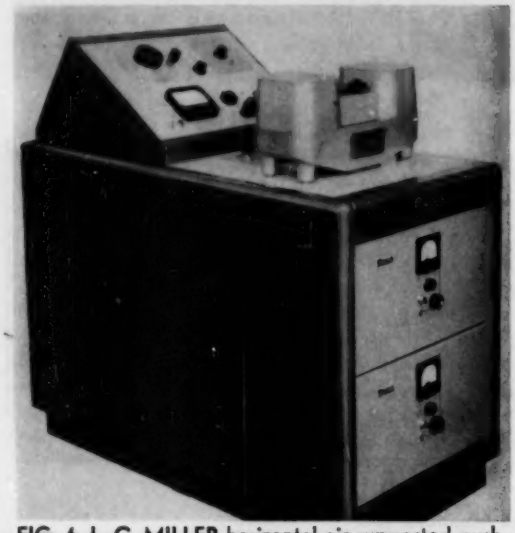


FIG. 6. L. C. MILLER horizontal air-supported push-pull-driven table and calibration console.

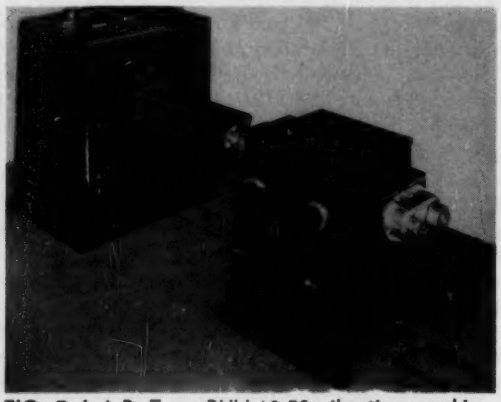


FIG. 7. L.A.B. Type RVH-18-50 vibration machine.

These machines are in extensive use in the electronic, aircraft, and automobile industry, and are suited to any type of testing where the frequency requirements of the test are within the range that can be produced by mechanical shakers. They feature reliability and ruggedness. Frequencies are indicated in cycles per second on the calibrated face of an electric tachometer.

High-frequency harmonic noise components present in this type of machine, although small in amplitude, are high in acceleration value and thus limit accelerometer calibration to low-frequency transducers.[2] Equipment and shock mount tests are an ideal and common use for this machine.

Fig. 4 shows Model 25-VP-D for vertical motion of 25 lb at 10 g and total displacement of 0.125". Maximum capacity is 23 g.

Genisco-Savage

Genisco-Savage lines of shakers and power amplifiers deliver thrusts to a test object equivalent to a control power of from 250 to 10,000 watts. Fig. 5 shows the Model V1001 system that develops an alternating thrust of ±3000 lb at an average of 10,000 watts control power.

L. C. Miller

The electrodynamic division of the L. C. Miller Company offers a unique concept in electrodynamic shaker design (Fig. 6). The shaker table is supported by air bearings which stiffly confine movement of the table in all directions but the axis of excitation. The air suspension system eliminates the springs and flexures used in other electrodynamic shakers. This reduces crosstalk or sidesway, a major consideration with most shakers.[3] The design, including the use of a drive coil at each end of the table, results in low distortion of driving waveform and cancellation of structural resonances. Users report no sidesway or crosstalk visible to 4 kc. Although the shaker is essentially resonant-free from 5 cps to 15 kc, amplifier harmonics may cause nonlinear results above 4 kc. Some sidesway effects may appear at several discrete frequencies between 4 and 25 kc. Maximum specimen weight is 5 lbs, table weight is 1.2 lbs, and force output is rated at 50 lbs. Evaluation of this data to obtain specimen weight-vs-g-force output is available in the literature.[2] An accelerometer calibration console (LCM-2210) or shaker units without amplifier and monitoring equipment are available.

L. A. B.

L. A. B. Corp. makes package testers, reaction vibration fatigue testers, large-force, high-frequency hydraulic vibrators, and impact testers. Package testers (Fig. 7) have dead-weight load capacities ranging from 400 to 10,000 lb; frequency ranges are from 2.5 to 5 cps.

Reaction machines use opposite-force actions to generate vibrations. Torque bar and cable suspension systems attenuate vibration transmission to the floor. They take loads from 50 to 10,000 lb, from 5 to 100

cps. Acceleration is up to 20 g. Generators produce thrusts in excess of 310,000-lb force.

Each vibration generator consists of two counter-rotating shafts to which are attached eccentric weights. The orbital motion of the weights are resolved into straight-line force vectors, with frequency from 5 to 100 cps.

The basic advantage of the reaction principle is that there is no requirement for external support. Another advantage is that direction of vibration can be changed from horizontal to vertical in less than 1 minute. A third advantage is that forces transmitted to the floor are relatively small.

The basic limitation is the 100-cps frequency limitation. Most common applications are in product testing.

The acceleration is calculated using formulas given by the maker. An accelerometer also can be used.

Ling Electronics

Ling Electronics makes complex-wave and sine-wave vibration test systems and complete vibration lab equipment (Fig. 8).

Model 6C, rated at 25 lb force, is designed for calibration and testing of pickups and small components. Model A-182 is rated at 25,000 lb force up to 2000 cps. Model 116, an ultra-low-frequency long-stroke shaker, has 3" stroke peak-to-peak. Ling also supplies related amplifiers, power supplies and a spectral density analyzer and spectral density equalizer.

Ling also has developed a line of oil-film slip tables wherein the test specimen is fastened on a slip plate which floats on an oil film. This reduces "cross talk."

The Calidyne Co.* offers a complete line of electrodynamic shakers with force outputs from 25 to 25,000 lbs. The driving principle is the same as that for a loudspeaker—that is, a conductor in a magnetic field is subject to a force proportional to current in the conductor.

The electrodynamic drive is more expensive than the mechanical drive but has higher frequency range (up to 2 decades higher), greater ease of control, and ability to generate complex waveforms such as random noise.

Environmental vibration testing is the most common application.

The relationship between thrust (force output) and control power is not simple, depending on frequency, load, and shaker design. An accelerometer is usually used on the table to measure the acceleration; some shakers have a built-in pickup.

MB

MB Electronics Co. makes a broad line of vibration amplifiers and exciters with output force capacities from 1.2 to 28,000 lb. Table loads can be up to 2,155 lb (10 g vector). Frequency band is to 2000 cps, to 6000 cps for sine wave.

One group of exciters ranges from zero up to 1200-lb and to 2500-lb force output, another group provides zero to 1750- to 5000-lb force, and a third group ranges to 7,000- up to 25,000-lb force. All permit operation from horizontal to vertical.

*Now a division of Ling Electronics.

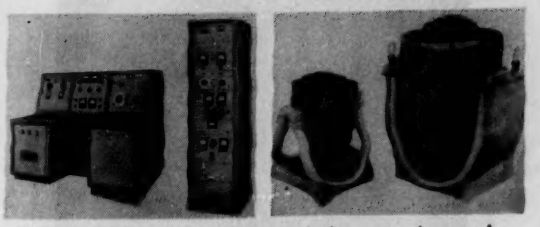


FIG. 8. LING equipments include control consoles and shakers.

FIG. 9. MB Model C125 is a 10,000-lb. force exciter with 1" table travel and frequency range from 5 to 2500 cps.

Wyle

Wyle Hydrashakers are electronically-controlled hydraulically-powered force generators. Their comparatively light moving assembly permits large "payload" capacities, such as 1000 lb at 17 g, or 25 lb at 100 g. Frequency can be up to 2000 cps.

The exciter tolerates temperature, altitude and humidity environments. Fig. 10 shows the W-4500.

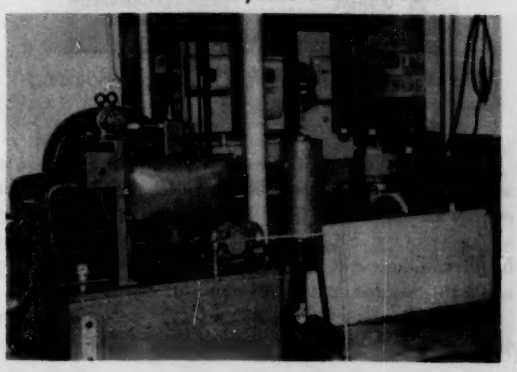
Shock Testers

Four basic types of shock-inducing techniques are in use—(1) weight swinging through a specific arc, (2) weight dropping vertically, (3) air cannon, and (4) pneumatic thrust machines.

Air cannon develop high accelerations (5000 to 50,000 g) at frequencies of 2 to 10 microseconds, but only for lightweight objects. The pneumatic thrust machine, such as the Hyge described here, is related to the air cannon.

In drop towers, the shock pulse is a function of the arresting medium, and can be varied greatly.

FIG. 10 WYLE Hydrashaker W-4500.



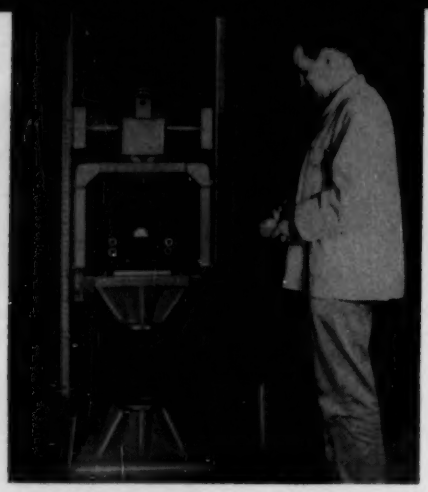


FIG. 11. BARRY varipulse shock tester uses gravity drop principle.

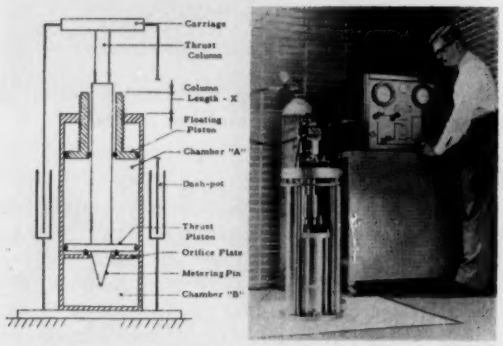


FIG. 12. CEC HYGE shock tester and principle.

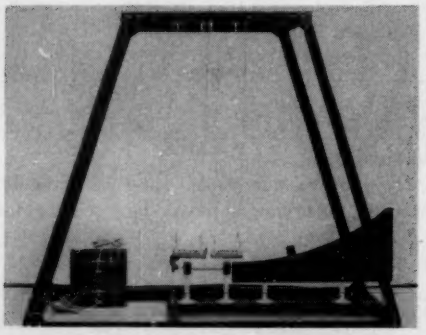


FIG. 13. GULTON Glennite ballistic pendulum.

In free-fall units, the test carriage is suspended at a height above an anvil. When released, the potential energy of its height is changed to the kinetic energy of its velocity. Shaped blocks of lead or plastic can be placed between the hammer and anvil to develop acceleration-time pulses of specific shapes.

The measurement of shock-pulse duration, form, and amplitude with an accelerometer must take into account its percentage of critical damping, mode of attachment, and characteristics of readout equipment. Failure to account for these parameters may cause gross measurement errors. [4,5]

Shock test usually specified is 11±1 millisecond per the requirements of MIL-E-005272B.

Barry

Barry Varipulse (Fig. 11) permits determination of peak-acceleration, pulse duration, and pulse shape independent of one another. Neoprene impact pads, lead pellets, or ram punches arrest fall.

CEC

The HYGE shock tester HY-6500 (Fig. 12), made by the Rochester Division of Consolidated Electrodynamics, is designed to generate in rapid succession either 11-millisecond ½-sine or 6-millisecond-sawtooth shock waveforms frequently called for in production line testing of small components. The unit stands 30″ high and has a 13″ square base, and comes completely assembled from the manufacturer. Energy source is either compressed bottled nitrogen at 2000 psi or compressed air.

To produce the shock pulse, the pressurized gas is introduced into Chamber A, forcing the piston down and compressing the "O" ring seal against the orifice plate. Additional pressurized gas is then introduced to Chamber B, acting on the much smaller area bounded by the "O" ring and orifice. As this latter pressure is increased, the upward force on the piston increases until the "O" ring seal is broken. The higher pressure in Chamber B then acts on the entire lower face of the piston, the unit fires and the shock is generated. Thrust at firing equals gas pressure in Chamber B times area of the lower piston face, less gas pressure in Chamber A times upper net piston area.

There are no shock-producing media expended during pulses. A metering pin is attached to the lower piston face. Operating through the orifice, it acts as a variable nozzle to control gas flow and the resulting thrust, throughout the waveform it defines. The carriage on which the specimens are mounted continues to travel after the displacement of the piston is arrested by pressure build up in Chamber A. The carriage is decelerated at a low g level by means of dashpots mounted axially about the periphery.

Other HYGE shock tester models are available from CEC to produce an infinite variety of shock waveforms including 5-g 100-ms square pulse; 2000-g 2-ms ½-sine pulse; 150-g, 30-ms ½-sine pulse, etc.

Gulton

Glennite ballistic pendulums (Fig. 13) provide an impact waveform of approximately a half sine wave with duration about 1 millisecond.

The gravity principle is used. Two identical precision machined masses, each weighing 60 lbs, are used to generate shock impulses. One mass is the driver pendulum; the other a follower pendulum. The driver is lifted a given distance along a calibrated scale to give clean mechanical shocks from 10 to 500 g. The follower is equipped with a built-in standard accelerometer. Operation is automatic.[5] Is said to be

"only integrated system with built-in standard accelerometer and cathode-follower filter system."

Under certain conditions the pulse width can be a limitation. AT-2 has nominal pulse width of 1 ms. with widths of 0.5 to 2 ms possible by use of special springs. Pulse widths to 10 ms can be provided.

Basic applications are in calibration of piezoelectric accelerometers and in shock testing.

Jan Hardware

Jolta shock testers made by Jan Hardware provide predetermined shock transients to an accuracy of 2%. Model S-200V has a range of 20 to 250 g for test weights up to 200 lb. Shock wave can have time duration of 2.5 to 30 milliseconds. The free fall of the carriage can be arrested by elastic, semi-elastic, or inelastic mechanisms.

The principle is that of the drop tower.

Angular Oscillators

The final method of providing a calibrated acceleration is by providing a periodic back-and-forth rotation. Thus a periodic, reversing acceleration is combined with a varying acceleration due to rotation. The hardware-store "paint shaker" is such a unit. Precision models usually provide low values of acceleration.

Genisco

Genisco has a new angular oscillating table (Fig. 14) that rotates in correspondence with a sine wave. The table is used for calibrating and evaluating damping and response of angular accelerometers and rate gyros.

Statham

Statham Model AAC-2 angular acceleration generator (Fig. 15) is a torsion pendulum with a 12″ table that provides low-decrement sinusoidal oscillations to a maximum amplitude of ±180°.

When the pendulum is deflected through a known angle and released, the resulting acceleration can be determined from the known displacement and period of the pendulum. The period of the pendulum will remain constant and the amplitude decay will be linear over several cycles if friction is small. A line drawn tangent to the peaks and extended to the zero time ordinate compares test accelerometer output to the calculated angular acceleration.

Micro-Gee Products Co.

Micro-Gee manufactures a line of angular oscillation tables that rotate in a rocking motion rather than a circular angular mode (Fig. 16). Frequency is variable between 0.1 to 50 cps, depending on model. Evaluation of natural frequency and response of gyros and accelerometers is possible. Another use is dynamic testing of automatic stabilization systems.[6]

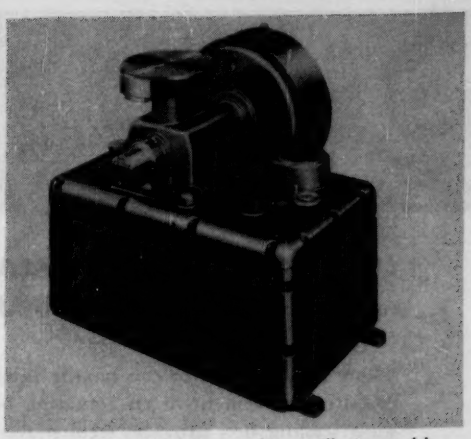


FIG. 14. GENISCO angular oscillating table.

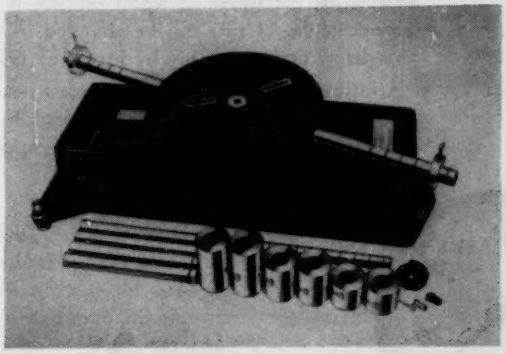


FIG. 15. STATHAM angular acceleration generator is torsion pendulum.

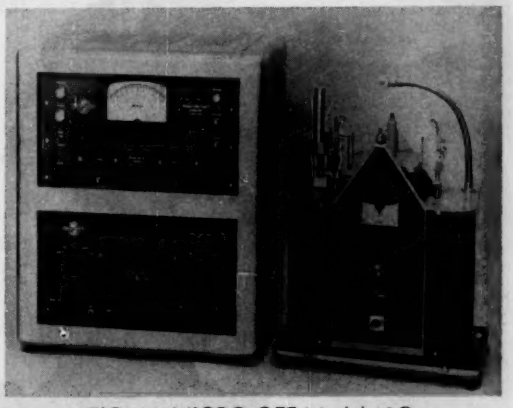


FIG. 16. MICRO-GEE Model 10C.

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6. B. W. McFadden, "Low Distortion & Low Noise in Small-Amplitude Motions," *Control Engineering*, July, 1956.

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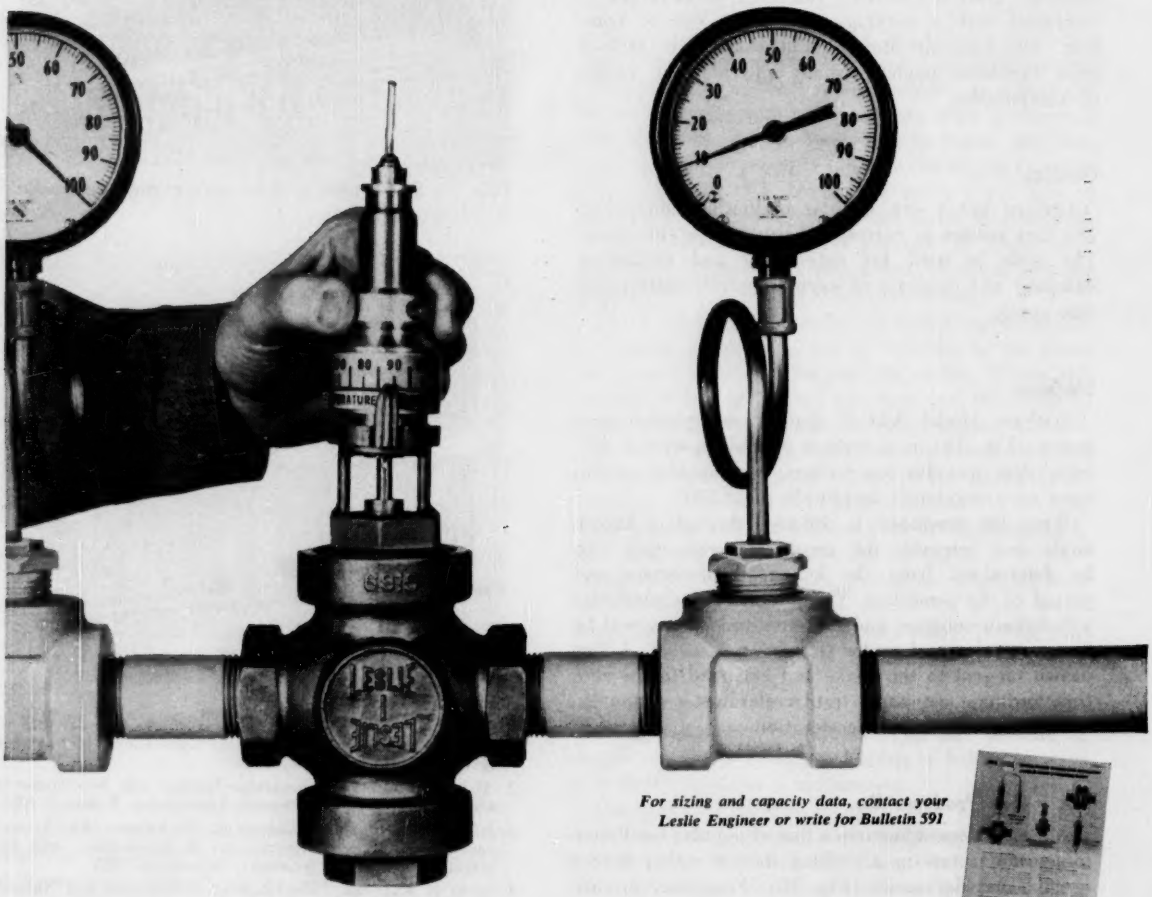
NEW SINGLE-SEATED, BALANCED DISC, TEMPERATURE REGULATOR HANDLES INLET PRESSURES TO 100 psi.

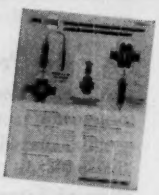
New Leslie regulator can handle inlet pressure and pressure drops to 100 psi. High power, positive movement of an actuating bellows with solid liquid fill, and the virtually friction-less stuffing box provides stem movement exactly proportional to the temperature change at the bulb.

Designed for steam or water service, it features a single seated, self-aligning, tight closing inner valve. (Units can be changed in the field from direct to reverse acting, or from reverse to direct acting, simply by inverting body and main valve.)

Applications include instantaneous heaters or coolers—shell and tube or shell and coil heat exchangers; storage or tank heaters; and, process heaters or coolers of all types. Available in cast iron or cast bronze bodies for temperatures to 450°F. Sizes ¾ and 1", screwed connections.



For sizing and capacity data, contact your Leslie Engineer or write for Bulletin 591



LC-10

CIRCLE 58 ON READER-SERVICE CARD

OTHER VERSATILE LESLIE REGULATORS PROVIDE PRECISE TEMPERATURE AND PRESSURE CONTROL.

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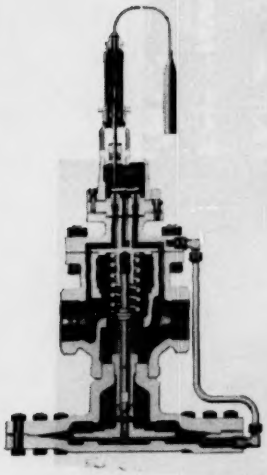
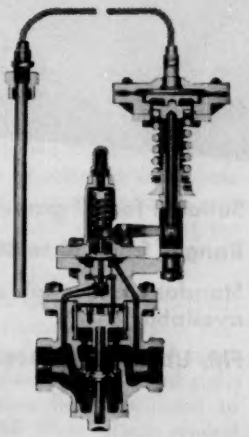
Direct Operated Design is used for small flow heating and cooling service, size ⅜, ½ and ¾". Liquid filled thermostatic element supplies ample power to stroke the single seated main valve. Valve travel is directly proportional to temperature change at bulb. This design is suitable for instantaneous and storage type heaters. It is also available in double seated construction for cooling service.



Class TKM Pilot Actuated, Metal Diaphragm Operated Temperature Regulator

Pilot Operated, Single Element Control also uses the liquid filled element to operate pilot device which applies operating pressure from the regulator inlet to a diaphragm for stroking main valve in heating or cooling service. Large diaphragm area and operating pressure supply ample power for controlling long stroke, single seated main valve with full flow capacity in sizes ½-4". Regulator has a 3 to 5° throttling range and is suitable for all storage type heat exchangers and for any system requiring on-off control.

Class LTCO Pilot Actuated, Piston Operated Temperature Regulator



Pilot Operated, Duo-Matic (two-element control) design offers both temperature and pressure regulating functions in a pilot actuated, piston or diaphragm operated regulator. The valves can handle a range of inlet steam pressures in heating services from 25 to 600 psi and controlled pressure ranges of either 2 to 15 psi or 10 to 250 psi. These characteristics are ideal for all storage type heaters and most instantaneous heater problems. Available in sizes ¼-6" with iron, bronze and cast steel construction.

For complete sizing and capacity data, write for Bulletin 5307-A.

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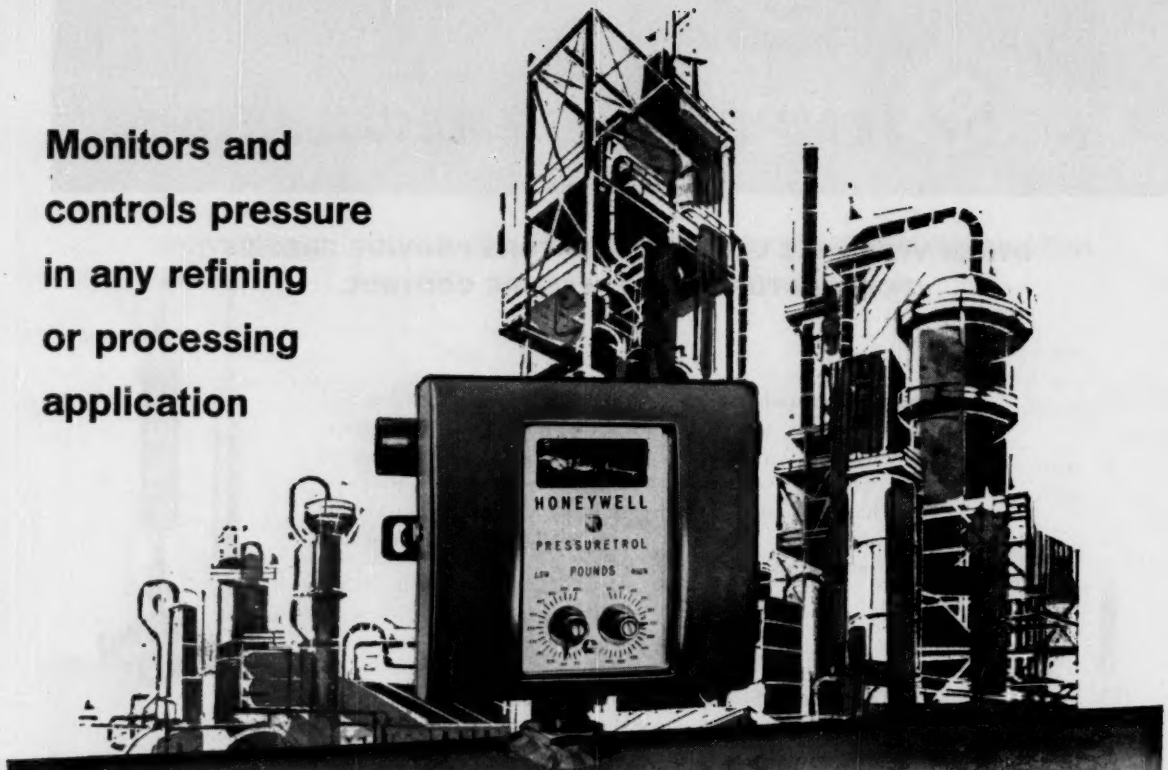

Honeywell's versatile Bourdon-tube PRESSURETROL*

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- **Ranges from 30 to 3000 psi**
- **Standard and explosion-proof models available**
- **FM, UL, FIA approved**

Honeywell Pressuretrols precisely measure and control pressures of any fluid, gas or steam. They can be used to sound an alarm or control a valve, pump or compressor. These are heavy duty devices designed specifically for industrial use.

The Pressuretrol can be flush or surface-mounted on a panel, or installed directly on a pipe. Settings are made with one high and one low pressure knob conveniently located on face of the unit. The mercury switch can be easily seen through a protective glass window. Depending upon pressure range, bronze, stainless steel and beryllium copper Bourdon tubes are available. Choice of control to make on pressure rise or fall.

Model P428		Model P444	
Range (psi)	Maximum (psi)	Range (psi)	Maximum (psi)
30—300	375	20" vac—40	75
50—600	750	1—20	50
100—1000	1200	5—50	80
200—2000	2400	5—150	200
300—3000	2500		

No matter what your pressure-control need, Honeywell can supply it for you. Call your local Honeywell office or write Honeywell, Dept. IC-2-41, Minneapolis 8, Minnesota. In Canada, write Honeywell Ltd., Seaside, Toronto 17.

See us in Sweet's 1960 Product Design File, Section 5b-Min.

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CIRCLE 59 ON READER-SERVICE CARD

Sound-level readings taken adjacent to punch press; operator has "noisefoe" over-ear cushion-type ear protector.

Sound, Noise and Hearing

These criteria can be used to evaluate possible harmful and costly effects of excessive noise, and to define what noise level is excessive.

NELSON HARTZ
Mine Safety Appliances Co.

SOUND AND NOISE have been defined in many ways—in terms of variations in pressure, stress, particle displacement and particle velocity in an elastic medium. To most of us sound is simply anything that we hear; sound is defined here as rapid pulsations in air pressure produced by a vibrating source.

Noise is generally thought of as unpleasant or unwanted sound. Noise may or may not be harmful to hearing, depending on its character and the conditions of exposure. However, noise is a problem to industry because (1) some industrial noise can damage ears, (2) workers claim compensation for loss of hearing which they attribute to harmful industrial noise, (3) noise can contribute to accidents.

One authority has called the question of noise in industry "the biggest single problem we have facing us under the Workmen's Compensation Law today." Estimates of amounts of claims filed througout the nation for "occupational disease" have been placed above a billion dollars.

Noise Damage

Noise usually does its damage in the inner ear. (There are exceptions—a sudden violent noise or nearby explosion can tear a hole in the ear drum; but this is rare, and prompt medical treatment can often undo the damage.)

The inner ear receives sound impulses from the three-boned structure of the middle ear (Fig. 1). The sound waves strike the ear drum and cause it to vibrate. These vibrations are passed on to the three bones (hammer, anvil, and stirrup) of the middle ear. From these bones the vibrations are carried to the watery fluid of the inner ear, and are converted into nerve impulses by delicate hair-like vibration pickups. Over-stimulation of these hairs by noise can cause them to wither or atrophy. When this happens, nothing now known can restore them. The hair cells convert the sound to nerve impulses to the brain; when they are damaged, hearing suffers accordingly.

Noise has a noticeable effect on a worker's nervous system. Increase in blood pressure and muscular contraction, which result in excessive fatigue and interference with the reception of danger signals and auditory communications, also have been attributed to high-level industrial noise. All these affect general safety.

Effect of Intensity

It has been claimed that (1) if the over-all noise level does not exceed 85 decibels, no injury to hearing results; (2) a noise level of more than 85 and less than 100 decibels may harm the ears of a highly susceptible individual after a long period of exposure; (3) noise levels above 100 decibels may do permanent damage after long exposure to the ears of a susceptible

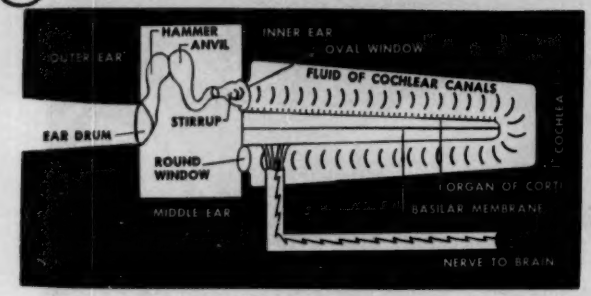


FIG. 1. THE OUTER EAR collects, funnels, and directs the sound waves. The middle ear transmits them. The inner ear analyzes the frequency and intensity of the sound.

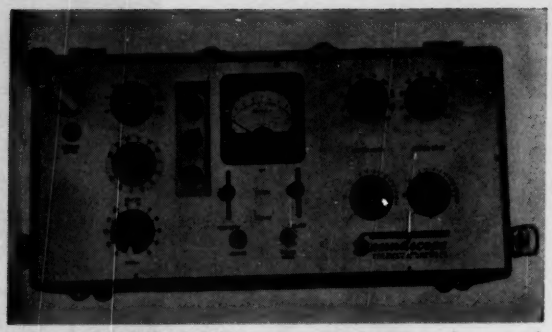


FIG. 2. SOUNDSCOPE has octave-band analyzer and narrow-band analyzer.

person, (4) noise levels in excess of 130 decibels can do permanent damage to the ears of normal persons, even after a relatively short exposure.

Table 1 shows typical sound-pressure levels as well as the relative energy generated by these levels. Note that a small increase in the decibel level results in a tremendous increase in the effective energy.

Effect of Frequency

The frequency or frequencies of the offending sounds or noise should be considered, in addition to the amplitude. Average hearing responds to frequencies from about 15 to 15,000 cps. The 88 keys of a piano range from a low note of 27.5 cps to a high note of 4186 cps. The human voice ranges from a basso's low of 80 cps to the high of a female soprano of about 900 cps.

The ear is most susceptible to damage from loud noises of the frequencies around 4000 cps. Apparently the outer- and middle-ear mechanisms have a higher transmission efficiency in the 4000-cycle region than at higher or lower frequencies.

Noise-Level Measurements

Industrial noise is complex because the noise made by a single operation can be composed of many frequencies varying in intensity. *Octave-band noise analyzers* are used to tell which bands and which frequencies are most offensive. For example, an over-all measurement taken near a milling machine resulted in a sound pressure level reading of 90 decibels. But readings taken from an octave-band analyer showed the frequencies of greatest intensity were in the lower ranges, and the intensity of the frequencies for which the human ear has the greatest sensitivity—from 2400 to 4800 cycles per second—was only 82 db. Fig. 2 shows a sound analysis being made near a punch press.

TABLE 1—TYPICAL SOUND PRESSURE LEVELS AND SOUND PRESSURES

Condition	Sound Pressure Level, db.	Relative Energy
Pain Threshold	130-140	
Feeling Threshold	120	10^{12}
Airplane, DC-6	104	
Very Noisy Factory	100	10^{10}
Subway Car	94	
Automobile	92	
New Streetcar	90	10^{9}
Street Corner Traffic, Large City	75	
Loud Radio	74	
Typical Office	60	10^{6}
Average Living Room	40	10^{4}
Very Quiet Home	20	10^{2}
Whisper	3	2
Audibility Threshold	0	1

Hearing Tests

The best method of ear testing now in common use employs an audiometer, (an oscillator which produces sounds of predetermined frequencies, usually 250, 500, 1000, 2000, 3000, 4000, and 6000 cycles per second), an attenuator which controls the intensity of the sound or tone produced, an interrupter switch, and an earphone through which the person being tested hears the tone.

There are three generally-accepted psycho-physical techniques used to determine threshold with the audiometer. Tests of these types should be conducted as soon as a man is employed and should be repeated at regular intervals. In this way the first signs of hearing deterioration will be detected soon after they have first appeared. Also, placement of employees who already have a hearing defect can be made with a great deal more care, and protection can be made available immediately. Removing a man who exhibits the symptoms of beginning a hearing loss from a noisy area—or providing protection—often restores full sensitivity. In no case is it wise to keep even men with normal hearing exposed to noises of high intensities and frequencies for long periods.

Key words in solving any industrial noise problem are: *reduction, isolation,* and *protection.* Reduction is the best solution. If reduction proves impractical, isolate the area from which serious noise emanates. Then personal protection should be made available to the men in the isolated area.

Noise Reduction

Noisy machinery often can be quieted by redesigning noisy parts. Lack of balance in rotating machines

FIG. 3. EAR insert protector.

FIG. 4. OVER-EAR cushion-type protectors.

can set up vibrations which are magnified by other parts, and restoration of balance can solve the problem. Resilient materials can be obtained for parts which are causing noise. Machinery covers can be damped with an undercoating material. Better foundation mountings can be obtained. Many other steps can be taken, depending on the nature of the plant.

Enclosures, either partial or complete, can be built around noisy areas or machines. Modern acoustical materials have made this job a great deal easier than it once was, but even these must be used in accordance with basic sound-deadening principles. The process can be inexpensive or expensive—a silencing structure for jet-engine test stands can cost as much as the rest of the testing installation. Isolation of noisy areas or machines usually does little for the men who must operate the machines or work in the area. For these, personal protection is the best answer.

Personal Protection

There are two basic types of ear protectors—the ear insert plug type (Fig. 3) and over-the-ear cushion type (Fig. 4). Each is designed to do a certain kind of job. Cotton or various swimmers' ear plugs give little protection against excessive noise. The ear plug or insert type of device is designed for general use. It provides excellent protection throughout the audio spectrum and reduces noise in the 4000-cycle region by about 40 decibels—the vibrational energy entering the ear of a worker in a noisy factory can be reduced about 99%.

The headgear type of protection device resembles a radio phone headset and has cushions (filled with either a grease-like material or plastic foam) which fit over the wearer's ears. It hushes loud noises, but passes spoken words in personal conversation or industrial signals such as bells, horns, and whistles. Such devices may be equipped with communication facilities.

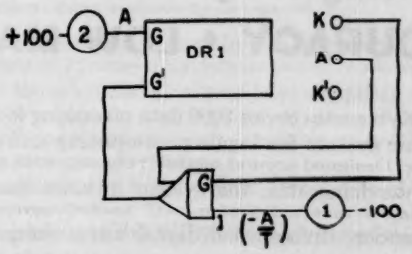
Simple Analog-Computer Sawtooth Generator

R. A. EUBANKS
Borg-Warner Research Center

Many analog computer simulations require the introduction of a periodic sawtooth function for use as a forcing function or trigger. This simple circuit has been found to have several advantages over others used for this purpose. It is stable in both peak amplitude, (A) and period (T), does not require an external frequency determining circuit, and contains few components. There is no interaction between the frequency control, potentiometer #1, and the amplitude control, potentiometer #2. If the required relay has multiple poles, the circuit can be used as a self-controlled instantaneous contact switch or pulse generator.

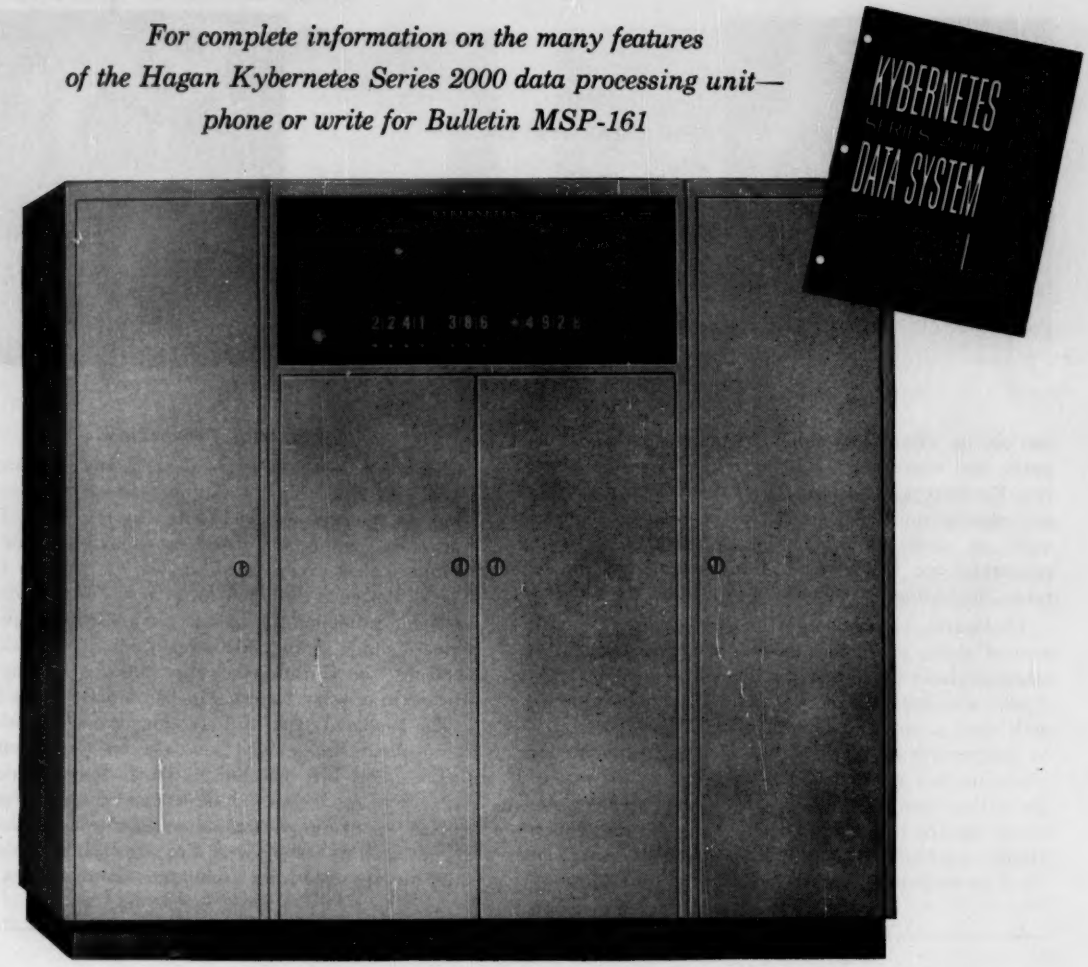
The circuit symbols used are those of Johnson*. DR 1 is a differential relay. In the figure, G and G' represent grid inputs to the relay amplifier. K and K' represent the two contacts of the relay and A is the relay arm.

*Clarence L. Johnson, *Analog Computer Techniques*, McGraw-Hill, 1956.



If G becomes more positive than G', the switches make contact between the arm and K. If G' becomes more positive than G, the arm will close with contact K'. A polarized relay can replace the differential relay shown, if the polarity of potentiometer #2 is changed. This generator is compatible with all operational computers known to the writer; the user must only verify that the relay shunts the integration capacitor and not a series combination of this capacitor and a grid resistor. This latter connection is possible with the Electronic Associates Pace Computers.

For complete information on the many features of the Hagan Kybernetes Series 2000 data processing unit— phone or write for Bulletin MSP-161



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Hagan Kybernetes Series 2000 data processing is an all-electronic system for logging, computing and alarm scanning. Designed around modular chassis, with similar types interchangeable, the system includes linearization, square root extraction, AC to DC conversion, multiplication, division and digital alarm comparison.

Here are some of the unique features of the Series 2000:

CONTINUOUS ALARM SCANNING—Alarm scanning does not stop during logging, trend logging or visual display of any variables.

HIGH SPEED A to D CONVERSION—This feature allows parallel functions such as computing and integration to proceed without interfering with alarm scanning and logging.

HIGH RELIABILITY—Modular construction of plug-in chassis provides reduced down time and no inventory problems.

HIGH ACCURACY—Simplified design and highest quality components provide an overall accuracy of ±0.1% of full scale.

PINBOARD PROGRAMMING—Pre-wired pin board makes selection of operational characteristics, or changing them, extremely simple.

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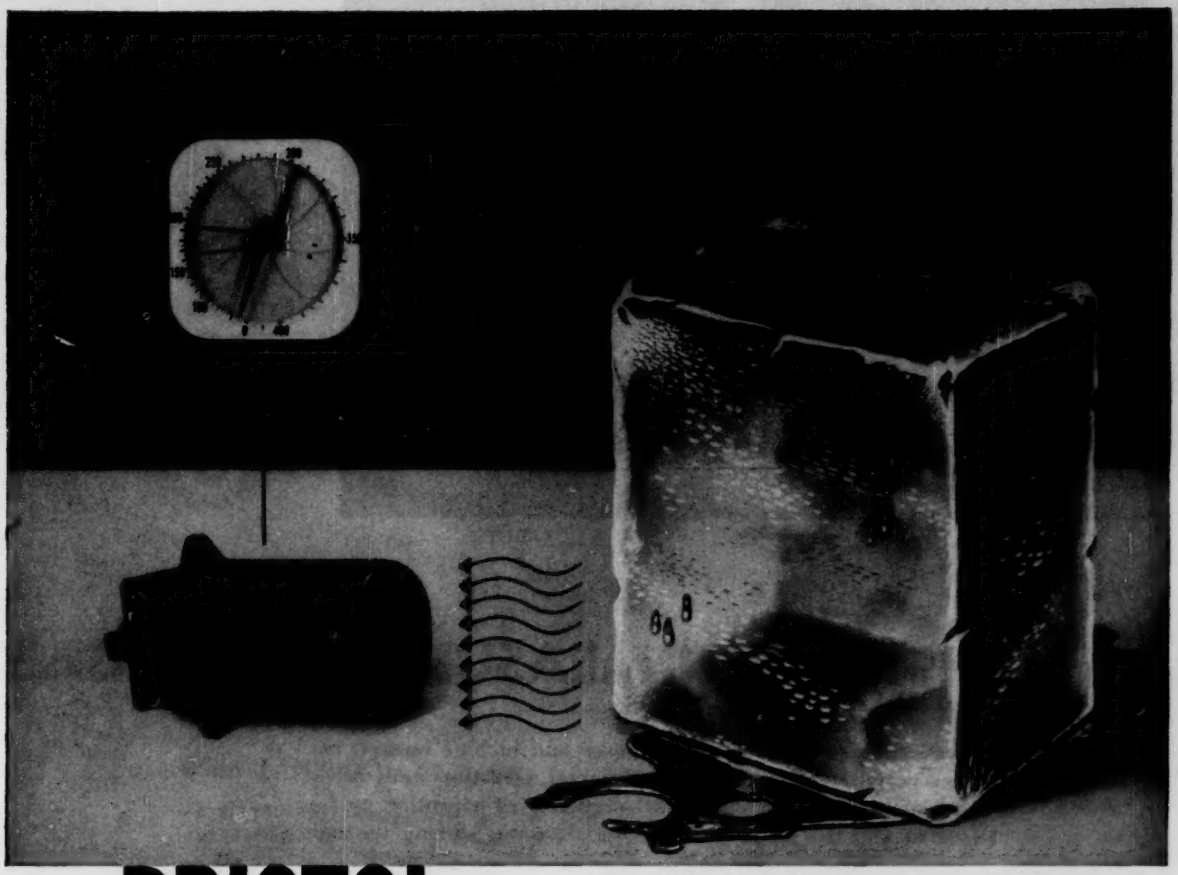

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AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

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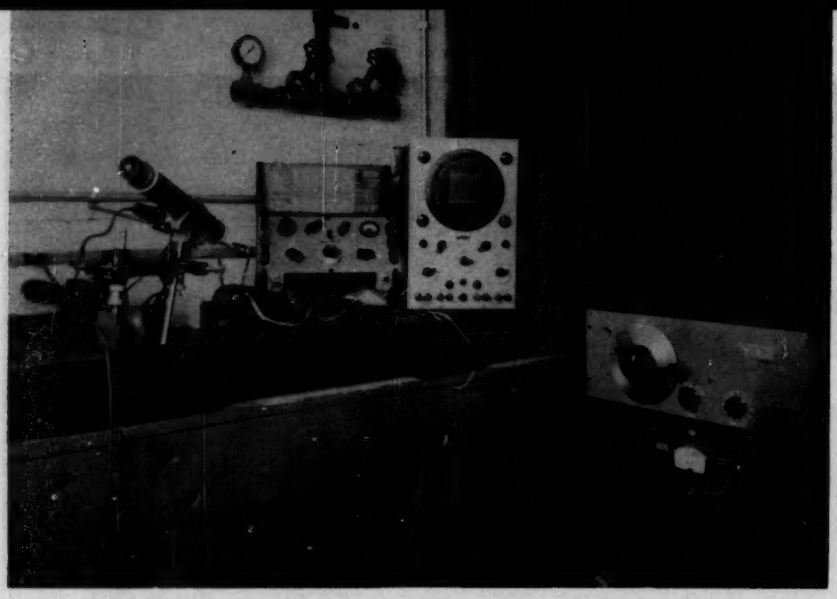

FIG. 1. BLADE VIBRATION test set up.

VIBRATION MEASUREMENT IN GAS

Instrumentation of compressor blades and turbine buckets requires certain preliminary experimental vibration and stress investigations to determine the frequency of vibration to be expected and the limits that will be allowable during testing.

FIRST TEST is made to determine experimentally the first bending-mode frequency-distribution curve for all stages of rotor and stator blades to be used in the test vehicle. Fig. 1 shows the vibration setup used. The test blade is held in a fixture designed to simulate engine clamping conditions, and is excited to vibrate by an electromagnet fed by a variable-frequency source. These tests check manufacturing quality and enable preselection of the blades to be instrumented for engine tests.

Nodal Configurations

Ten blades from each stage of the compressor are tested for frequency analysis. Fig. 2 shows the typical nodal patterns obtained. Nodal patterns are determined by one of two methods. The first and original method consists of sprinkling a small amount of sand on the flat portion of the blade while the blade is in motion. Where the acceleration is less than 1 g the sand will build up, forming the nodal points. These formations are called "Chladni Figures," named for the man who developed this technique.

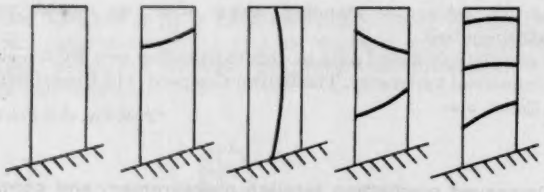

FIG. 2. COMPRESSOR rotor blade nodal patterns.

The second method, developed for surfaces that are not applicable to the Chladni technique, uses external vibration pickups. The pickup is used to explore the blade surface and its output is fed into the vertical plates of a cathode-ray oscilloscope. The output of the blade-exciting (driving) frequency is imposed on the horizontal plates and, by observing the phase shift of the resulting Lissajous figures as the pickup is moved, the nodal line can be defined. When the pickup traverses a nodal line the pattern on the oscilloscope will shift 180°.

Stress Distribution Curves

Prior to instrumenting the compressor blade it is necessary to predetermine the optimum strain-gage location to give maximum coverage for the modes of

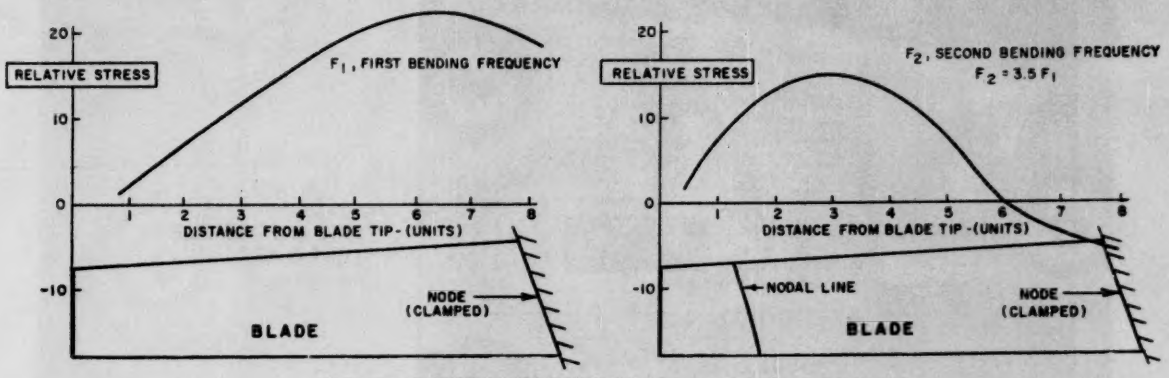

FIG. 3. STRESS DISTRIBUTION of rotor blades.

TURBINE BLADES

DANA A. MORLEY

Small Aircraft Engine Dept.
General Electric Co.

vibration that may be excited to vibrate during test. This is done both analytically and experimentally. Fig. 3 shows typical stress distribution curves for two bending modes. The data used in preparing these curves are obtained by attaching strain gages to the airfoil section of the blade. The blade is held and excited to vibrate in the same manner as described previously for the frequency-distribution studies.

Stress Endurance Curves

One of the prime factors in establishing safe operating limits for compressor blades during test operation is the stress endurance level of the blades. A strain gage is attached to the blade at the point of maximum stress and the blade is held in a fixture simulating engine clamping. A curve of stress vs blade-tip amplitude is obtained by vibrating the blade in its first bending mode.

The blade is then vibrated at a preselected amplitude for 10^7 cycles or until failure occurs. This process is repeated on approximately ten blades at varying amplitudes, or until a satisfactory stress endurance curve is obtained.

Electronic Instrumentation

Many blades on each rotor are equipped with strain gages and leads brought out through special commutators. After delivery of the test vehicle to the cell, the output leads from the strain gages are connected to the portable instrumentation cart. Fig. 4 shows how the portable instruments used are arranged. The numbers shown identify each item discussed below.

1. **Transducer Panel.** The transducer panel provides the means of connecting the strain gage lead wires from the test vehicle to the rest of the equipment and provides connections for energizing the gage circuits with direct-current power. Switches and jacks permit gage voltage-drop and resistance checks, even while the engine is running. It also provides connections for feeding the strain-gage output voltage to the calibration panel.

2. **Calibration Panel.** The calibration panel is used to adjust the amplifier gains so that maximum allowable stresses for each gage can be set to show as a certain height of voltage wave shape appearing on the monitoring oscilloscopes. By knowing the electrical parameters of the strain-gage circuits, peak-to-peak stress can be represented as an equivalent rms voltage. The calibration panel enables this rms voltage to be switched to the input of the amplifier corresponding to the strain-gage channel to be calibrated.

3. **Amplifiers.** The amplifiers convert the low-level strain-gage output voltage to a higher level more suitable for observation and magnetic-tape recording. Gain is better than 1,000 to 1, with excellent frequency response characteristics. Included are calibrated step attenuaters plus a vernier gain control. The outputs of the amplifiers are fed to a patch-panel and from there to the various monitoring and recording devices.

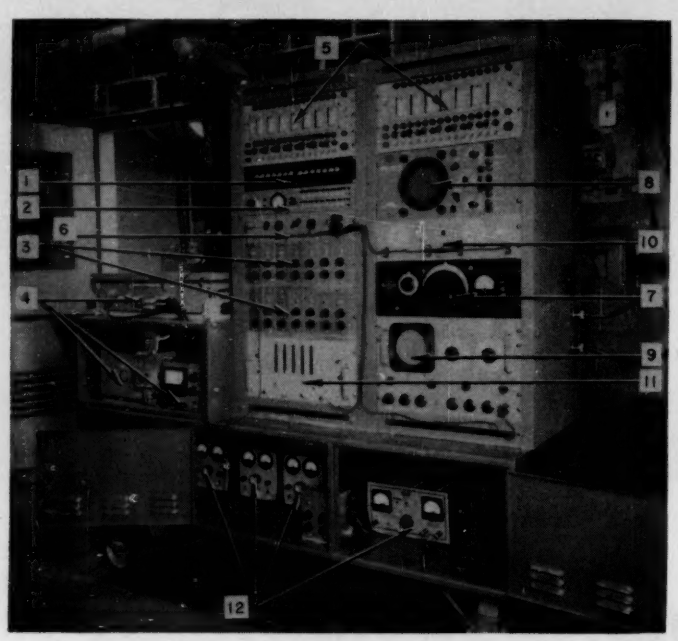

FIG. 4. PORTABLE TEST CART instrumentation.

4. **Magnetic Tape Recorder.** The recorder is used simply as a memory device, capturing and retaining the electrical signals put out by the strain gages. The model shown is a 14-channel airborne magnetic-tape recorder.

5. **Multichannel Oscilloscopes.** The oscilloscopes are used to observe the electrical output signals from the strain gages for interpretation during engine testing. The height of the wave shapes is a measure of the blade stress amplitude. The frequency and wave shape of the signal indicates the mode of the blade vibration.

6. **Selector Switch Panel.** The selector switch panel provides a means of selecting individual channels for display on other indicating instruments, for connecting into the circuit band-pass filters for individual signals, or for selecting speed signal or oscillator frequency for direct readout on a frequency meter.

7. **Oscillator.** The oscillator is a variable-frequency signal source used to supply the calibration signal for setting the amplifier gains. It also is used to supply the reference frequency necessary to determine the blade vibratory frequencies by Lissajous figures on the oscilloscope.

8. **Single-Channel Five-Inch Oscilloscope.** The multichannel oscilloscopes have relatively small size screens, and at times it becomes necessary to observe a larger presentation of various signals. The five-inch oscilloscope is used for this purpose. Any one of the fourteen small scope signals can be selected through the switch panel for observation on the larger scope.

9. **Sonic Analyzer.** The sonic analyzer gives a rapid indication of both frequency and amplitude present in the complex waves frequently observed in strain-gage output signals. The stress and vibration engineer can tell at a glance the mode or modes of blade vibration and also the relative amplitudes present in the signal. Again any of the fourteen channels can be observed on the analyzer.

10. **Band-Pass Filter.** The band-pass filter can be inserted in the system to filter out unwanted frequency components from the signals applied to the five-inch oscilloscope or sonic analyzer presentation. In this manner it is possible to isolate the desired signal from noise or spurious signals, so that critical low-level signals can be observed with less chance of wrong interpretation from confusion with other signals.

11. **Frequency Meters.** The frequency meter is an "events-per-unit-time" indicator. Either engine speed, oscillator frequency or one of the fourteen-channel signal frequencies can be displayed on the meter by a selector switch.

12. **Power Supplies.** The power supplies provide d-c strain-gage excitation power, and also the plate and filament voltage for the strain-gage amplifiers.

Data Reduction

Fig. 5 shows the equipment in the new data-reduction system. The major components are:

1. **Magnetic-Tape Playback Recorder.** The magnetic-tape playback recorder plays back the tapes recorded at the test site. This recorder can handle both amplitude-modulated and frequency-modulated records. It is equipped with a speed control to allow playback at both higher or lower speeds than during recording of data.

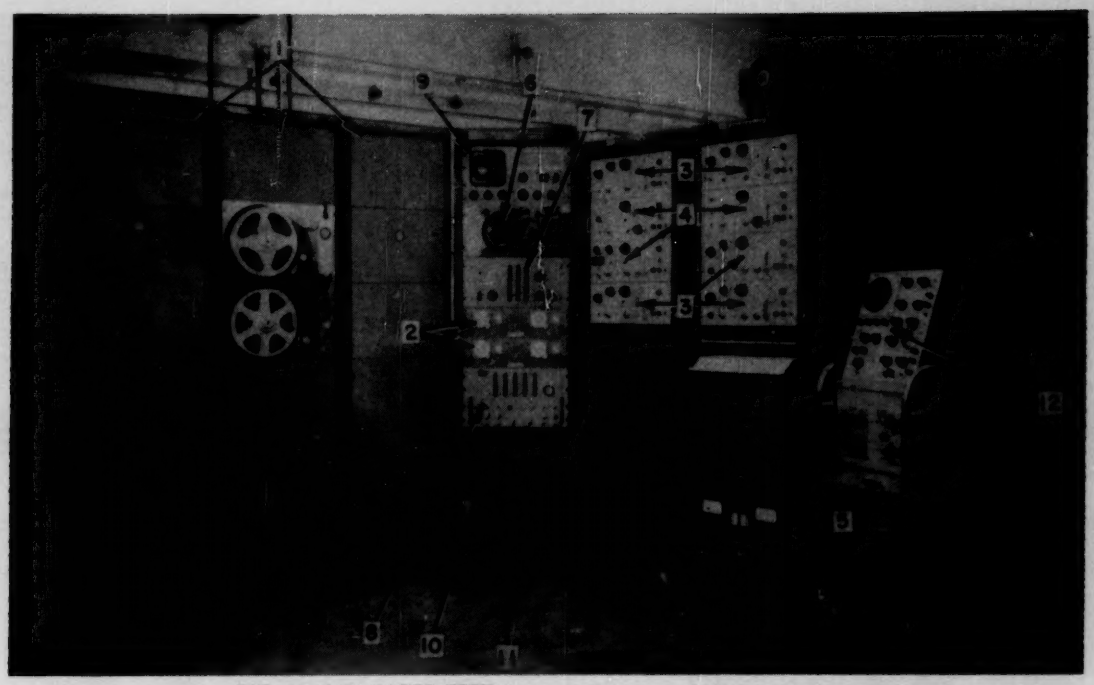

FIG. 5. COMPLETE TEST instrumentation and data reduction.

2. **Band-Pass Filters.** The output of any channel of stress recording would normally be a complex signal. The band-pass filters separate the various components of the complex signal and select the particular mode to be analyzed.

3. **Log Audio Preamplifier.** The output of the filter is applied to a log audio amplifier which operates on the signal to create a d-c voltage proportional to the amplitude level of the original a-c signal.

4. **Frequency Level Preamplifier.** The output of the filter is applied to a frequency level amplifier, which operates on the signal to create a d-c voltage whose level is proportional to the frequency of the original a-c signal.

5. **Direct-Writing Recorder.** The output of the log-audio preamplifier and the frequency level pre-amplifier are fed into the direct-writing recorder. Thus a direct reproducible print of the d-c voltage level is impressed on a roll of paper, which is a direct representation of the amplitude and frequency of the original stress signal.

Engine speed is measured in terms of frequency, and it also can be expressed on direct-writing paper as a d-c voltage level whose amplitude represents engine speed.

Calibration signals and zero-suppression circuits incorporated in the direct-writing recorder permit small changes in frequency or stress amplitudes to be presented over the full chart width; thus excellent readability and accuracy can be realized.

6. **Oscilloscope.** The oscilloscope permits any one channel of tape information to be monitored during analysis to observe wave shape, determine proper band-pass filter characteristics, etc.

7. **Oscillator.** The oscillator provides a source of calibration voltage to determine the frequency of various signals and as an aid in setting zero suppression in the recorder circuits.

8. **Electronic Frequency Meter.** The electronic frequency meter is used to obtain accurate frequency readings of both engine speed and blade vibration frequencies.

9. **Sonic Analyzer.** The sonic analyzer is used to quickly ascertain the components of any of the stress signals.

10. **Patch-Panel.** The patch-panel provides a means of inter-connecting the various channels of tape information with the various channels of direct-writing equipment.

11. **Audio Play-Back System.** One channel on the magnetic tape recorder is used for voice comments during test. The audio-play-back system enables the analysis engineer to monitor these comments during analysis of the data.

12. **Tektronix Scope and Digital Voltmeter.** This equipment determines calibration levels and handles routine maintenance of all data analysis equipment.

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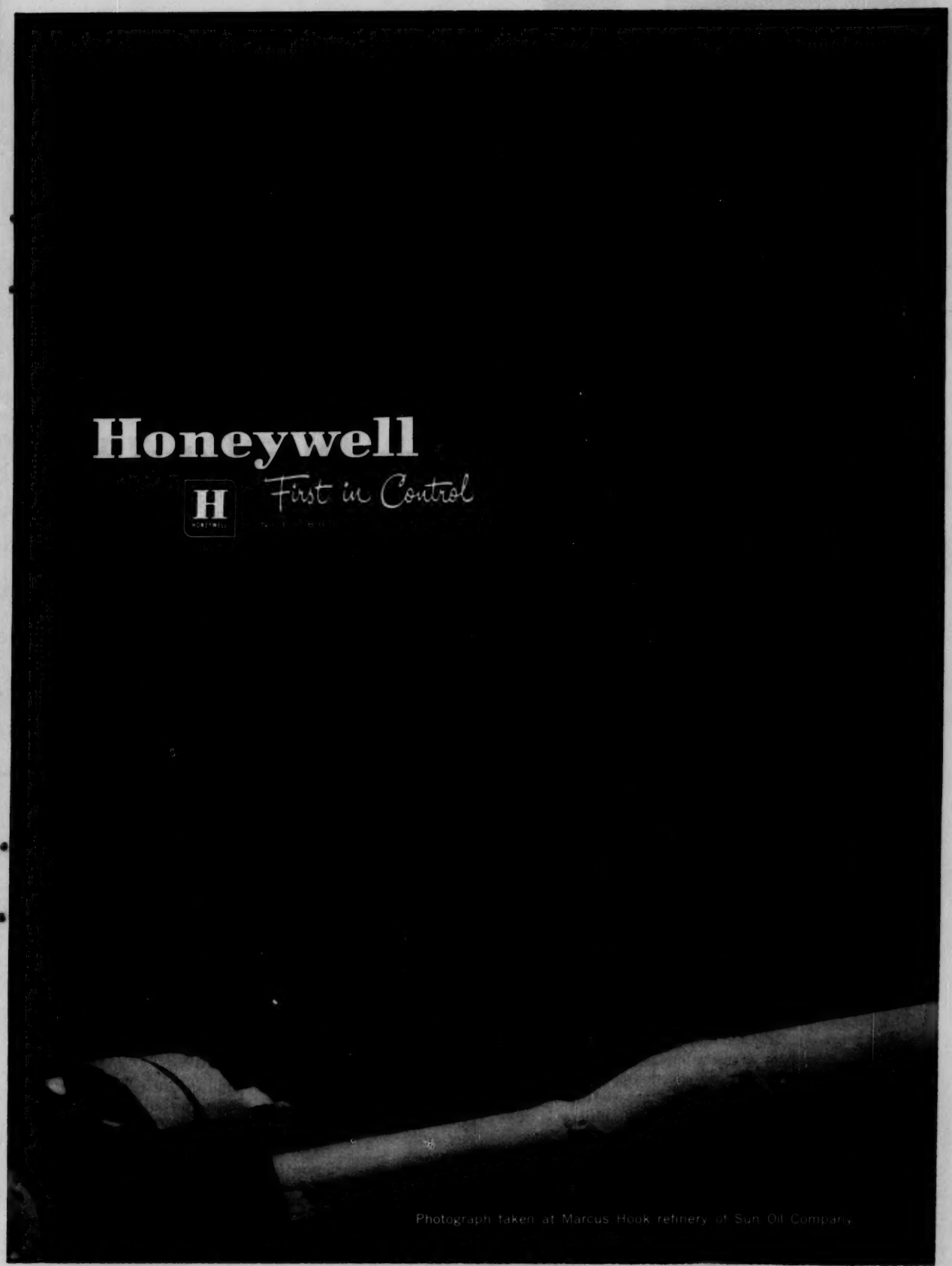


Photograph taken at Marcus Hook refinery of Sun Oil Company

CIRCLE 62 ON READER-SERVICE CARD

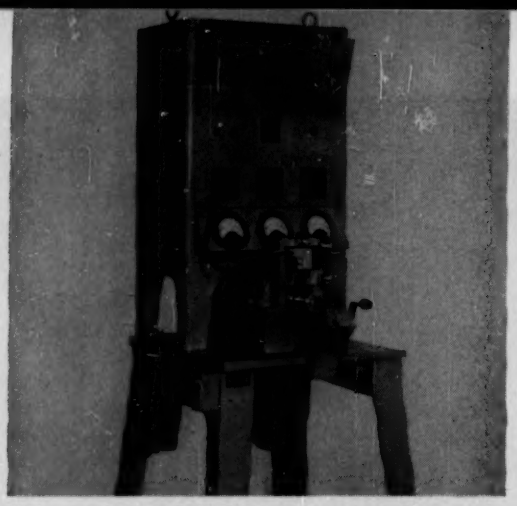


FIG. 1. ANDEROMETER has three band-frequency selections and loudspeaker. (Courtesy Micrometrical Mfg. Co.)

FIG. 2. SMOOTHRATOR features a velocity pickup, several stages of amplification, and a dwell level indicator. (Courtesy Barden Corp.)

Quality Control in Bearing Manufacture and

Among the important quality factors to be controlled in the production of instrument bearings is vibration. Here is a survey of available techniques for measurement of bearing vibration and a state-of-the-art review of the quality-control standards of bearing manufacturers.

A VIBRATION COMMITTEE was established in 1953 by the American Ordnance Association. The committee split into two groups—one to study vibration testing and standards outside the instrument and bearing industry, the other to poll instrument and bearing companies. It was the committee's view that vibration measurement should become the means for evaluating ball bearings used in gyro rotors and other high-speed motor applications.

A survey was made in the following points: What load should be used in tests? What speed? What type of load? What load inertia? What axes position? What type of race rotation? How should misalignment be handled? What mode of measurement should be used? What unit of measurement? What frequency ranges? What specific frequency?

The Vibration Sub-Committee realizes that the successful bearing tester specifications must include *basic calibration means*. Unfortunately, this portion of the art of vibration measurement has enjoyed little development. Electrical calibration of amplifiers is a straightforward procedure, but over-all checking through the pickup involves an exciter source. The exciter must in turn then have its own calibrator.

The National Bureau of Standards has done some work on an exciter calibrator. The cost and complication of the combination of their equipment, however, would prevent general use. The committee has considerable work ahead in this area. The following is a survey of available vibration testers.

Anderometer

One of the earliest commercial vibration testers designed strictly for ball-bearing inspection is the *Anderometer* (Fig. 1). Today there are about fifty in use. The instrument features a built-in drive at 1,800 rpm with optional hand or mechanical loading, axially. The velocity pickup senses the radial mode of vibration. Electrical calibration is with metered oscillator inputs.

It gives a numerical rating of the combined irregularities of the balls and raceways. The unit of measurement is the *Anderon*, and takes into account both the angular spacing and amount of "throw" of the complex cam action caused by this combined waviness (in terms of micro-inches of height) and number of "throws" per circumference.

The Navy finds this device useful in specifying quiet bearings of larger-than-instrument sizes for submarine use.

Smoothrator

The Barden *Smoothrator* is perhaps the best-known vibration measuring device in the instrument ball-bearing field. Fig. 2 shows the unit. It features a velocity pickup (coil-magnet), several stages of amplification,

FIG. 3. VANT unit is automatic, with the exception of loading and unloading of bearing. (Courtesy Miniature Precision Bearings, Inc.)

FIG. 4. FAFNIR acceleration-type pickup checks axial vibrations at 10,000 rpm inner-ring rotation on a horizontal belted drive. (Courtesy The Fafnir Bearing Co.)

VIBRATION MEASUREMENT

M. H. ARONSON

and a dwell level indicator (which registers the average signal produced by normal rolling contacts). Relatively constant average signals are produced by the normal rolling contracts within the bearing. It also has a counter tube that registers the peak or transient signals produced by dirt or gross irregularities of the balls or raceways over a given time cycle.

Calibration of this counting circuit is performed in an ingenious manner by dropping 1/16" steel balls from a given height into a steel cup fastened to the pickup spindle. Calibration of the over-all dwell level is by master bearing comparison. Its speed of rotation is a coast-down range from 600 to 300 rpm.

Vant

The *Vant* (Fig. 3), short for *v*ibration *a*nd *n*oise *t*ester, is made and used by Miniature Precision Bearings, Inc. This is the most recently designed unit to come to the attention of the Vibration Sub-Committee. The electromagnetic velocity pickup and amplifier puts out a single over-all vibration reading. This unit is entirely automatic with the exception of loading and unloading the bearing. The desired speed of rotation for the test can be preselected from 0 to 7,500 rpm. The desired level of rejection also can be pre-set. When the start button is pushed, the "umbrella" is air-driven to speed. Then the air is cut off and the amplifying circuit cut in. The meter shows the vibration level and a red light goes on if the reading has exceeded the pre-set rejection level.

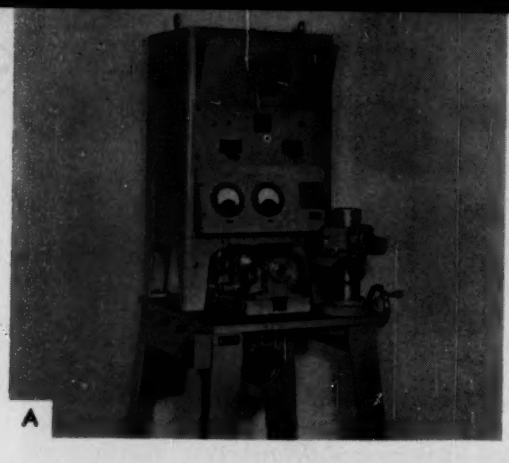
A random vibration would, in general, have both an axial and a radial component. The axial component is the easier one to measure because a great amount of motion results in this direction. The radial component would be opposed in all directions by the other race; in other words, the bearing is "stiffer" in the radial direction. Therefore, means of measuring the axial motion of a bearing in a test application would indicate the quality of performance.

The MPB Vant fulfills the need for a method to measure axial motion, as follows:

A vertical shaft supports the bearing through the inner race. The bearing, in turn, supports a cylindrical weight called the rotor. When the rotor turns, vibration generated in the bearing causes the vertical shaft to move. The shaft is able to move because it is held by two very flexible discs. On the end of the shaft is fastened a coil of fine wire, around which is a strong magnetic field from a permanent magnet. As a result of axial motion, a voltage is generated in the coil. The amount of this voltage is proportional to the amount of motion. The motion meter indicates the highest recurrent motion or velocity in microns per second. This meter is located on the front panel of the Vant, close to a small oscilloscope that reveals the nature of the vibration.

The speed of the rotor is controlled by setting the high limit hand on the rpm meter. A speaker is mounted in the cabinet to amplify the sound.

On the Vant control panel is a time totalizer which measures seconds. This timer starts when the rotor reaches the speed set by the high limit hand and runs until the speed of rotation of the rotor drops to



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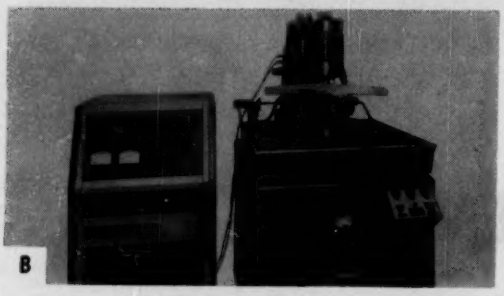

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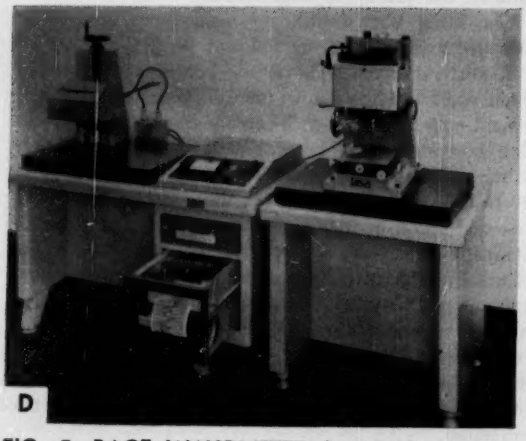


D

FIG. 5. RACE WAVOMETER for checking ball track peripheral deviations from true roundness in rms millionths of an inch (A). Vertical Wavometer with tracer measuring the bearing race (B); **RACE FINISH** is checked on a Profilometer (C); bottom illustration shows Proficorder for recording a roughness profile, linear (left) and rotary (right). (Courtesy Micrometrical Mfg. Co. and Fafnir Bearing Co.)

wherever the low limit hand is set. The timer makes it possible to compare the spin-down time of two bearings between two levels fixed by the high and low limit hands. The spin-down time indicates how easily the bearing turns.

Vibra-Meter

The *Vibra-Meter* is another "umbrella type" accelerometer pickup. It features hand-spin outer ring rotation under axial loads of 70 to 90 grams. It is sensitive to vibrations ranging in frequency from 200 to 1,000 cycles at about 100 rpm. Its peak level indicators are calibrated from a metered 400-cycle oscillator input which bypasses the pickup. Over-all calibration is achieved by master bearing comparisons. This tester is commercially available from Leitch-Huard Corp.

Fafnir Vibration Tester

Another acceleration-type pickup is used at Fafnir (Fig. 4). This unit checks axial vibrations at 10,000-rpm inner-ring rotation on a horizontal belted drive. An over-all reading is taken when the bearing is loaded axially by hand. Calibration is by crystal exciter driven by a metered oscillator input of 400 and 1,000 cps.

This unit was born of necessity to check bearings for a 14,000-rpm motor which developed undesirable coast-down resonances. It became apparent after study that axial vibration measurement at the critical speed was the only answer.

Bearing Analyzer

The Model BA-20 Electronic Bearing Analyzer of Bearing Inspection, Inc., occupies 18″ x 18″ of bench space (Fig. 6). It can determine the quality of ball and roller bearings, new or used, lubricated or dry.

Condition of the bearing under test is indicated visually by oscilloscope display and db meter, and audibly by a speaker. Rejection is automatically indicated by a red light. User can set own rejection standard, or a standard can be built in at the factory. The complete inspection can be made in from one-half to two minutes, depending on the type of bearing.

The machine makes a 100% check of all the active surfaces of ball and roller bearings including the entire surface of the steel balls. It will indicate a fault and its comparative size on any of the active surfaces of a bearing, whether on the outer race, inner race, retainer or balls. It also indicates foreign matter in the lubricant. In the case of the inner race, the exact location of a fault is indicated. Torque is indicated by comparison with a bearing of known quality.

The basic principle utilizes a sensitive vibration pick-up coupled to a controlled drive mechanism so constructed as to permit the scanning of the entire bearing surfaces. Bearing Inspection, Inc., also offers an automatic bearing cleaning center.

Control In Manufacture

For years manufacturers have searched for ways and means to build smoother-running bearings. This search already has lead to extensive quality-control instrumentation. In addition, large investments have been made in research equipment to analyze the causes of noise and vibration in a bearing.

These investigations have influenced the design of the machinery used to manufacture bearings. For example, two-ton grinding machines may operate upon a bearing part weighing only a few grams. The necessity to get rigidity and smoothness into the same machine accounts in great part for this combination.

A common practice in bearing plants is to check for vibration in the grinding machine. This is important because wheelhead vibration can cause chattered ball races. *Race waviness* and *surface roughness* are prime vibration sources.

Surface Roughness

A quality-control instrument used to measure circumferential chatter and waviness in inner and outer races is the *Race Wavometer* (Fig 5). The rms average microinch height of waves that repeat four to fifteen times per circumference are indicated on one indicator, and waves repeating sixteen to forty or more times show on a separate indicator scale. An oscilloscope shows the number and shape of waves per revolution in either waveband. The bearing ring is rotated by a drive spindle at 1,800 rpm. The pickup is either hand held or piloted. A loudspeaker enables the operator to detect deviations in quality by ear.

The *Vertical Wavometer* (Fig. 5B) will give the same information as the standard unit but will accommodate parts up to 18″ in diameter, instead of the maximum of 6″ provided by the standard wavometer.

Race finish, so important in the control of noise and torque, is checked on a *Profilometer* in Fig. 5C, with special oscillatory scanning. Race finishes for instrument bearings now are of amplitudes under one-half micro-inch.

The Profilometer can measure average surface roughness height in microinches, either arithmetical or rms. Basically, the instrument consists of (1) a tracer, which is moved either by hand or mechanically over the surface being measured; (2) a portable "amplimenter" unit, connected to the tracer by a cable; and (3) a motor-driven mototrace or "pilotor" for operating the tracer where manual operation is not practical.

The *Microcorder* is an electro-mechanical instrument which provides a permanent magnified chart record of the roughness profile of a surface.

The *Proficorder* is another instrument for producing a pen-drawn chart of the surface showing the shape, spacing and microinch height in accurately readable form (Fig. 5D).

Race contour and form can also be checked with air and electric gages. The old visual and optical methods are fast being superceded.

Talyrond

Laboratory precision measurements of race and ball geometry are made on the *Talyrond* (Fig. 7). This is an English instrument which reads displacements directly to an accuracy of 0.000002″. For instance, in one circumferential scan it can record race finish, waviness, chatter, and roundness at 10,000 magnification. It can read across-the-race curvature as well as show variation from true form. It also checks sphericity and waviness of the ball surface. Finish indication is limited by the radius of the tracer.

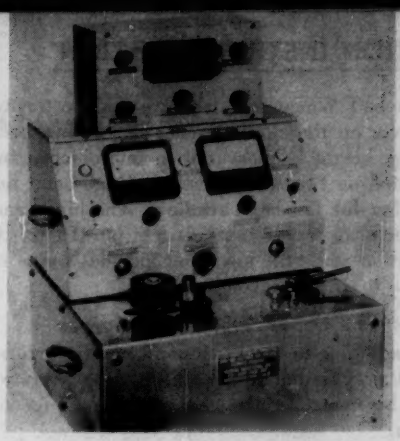


FIG. 6. BEARING ANALYZER Model BA-20. (Courtesy Bearing Inspection, Inc.)

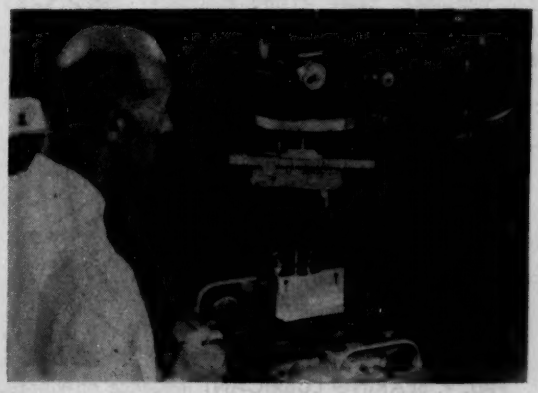


FIG. 7. TALYROND is used for precision measurements of race and ball geometry; has 2 microinch accuracy. (Courtesy Fafnir Bearing Co.)

FIG. 8. BALL WAVOMETER is used in production to control waviness of balls (Courtesy Fafnir Bearing Co.)

Ball Wavometer

In production, the control of waviness of balls is based on the *Ball Wavometer* (Fig. 8). This instrument operates similarly to the race Wavometer, but the rotational speed is slower. Ball waviness is held in the region of one microinch. Special scanning adapters implement the Profilometer so that it reads ball surface finish to tenths of a microinch.

The ball Wavometer measures the average height of waves on the circumference of bearing balls. The average height is measured in microinches rms and indicated on two meters, one for high-band readings, the other for low-band readings. The high-band reading includes waves that occur from 16 to 100 per revolution while the low band includes waves ranging from 3 to 16 per revolution.

Other Vibration Sources

In addition to the obvious geometric errors, there are other possible sources of bearing vibration that must be controlled by manufacturing procedure or design.

Ring unbalance due to eccentricity of section is an item that, within normal limits, is controlled by balancing at rotor assembly. The concentricity of the retainer piloting surface must be held closely, however. Retainer unbalance cannot be compensated by rotor balancing and thus its dimensions, clearances over the piloting surface, and ball pocket play must be held to specified values.

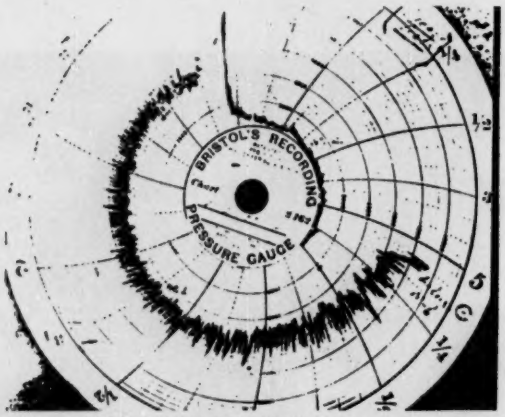
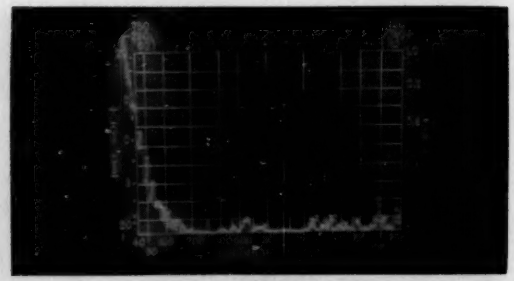


FIG. 9. BEARING LUBRICANT influence on vibration level. Broad trace is made by high, varying torque of "working" grease. Low, even torque trace is with channelling grease; blips reveal grease re-entry into ball track.



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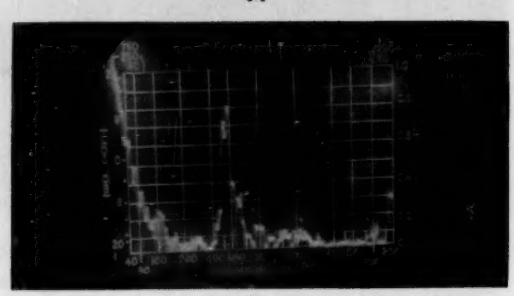


B

FIG. 10. PANORAMIC ANALYSIS of a good bearing (A) with only a few vibration peaks; B shows panoramic analysis of the same bearing slightly misaligned.

Bridging and errors in *ball spacing* account for some vibration due to differential deflections for the various ball positions during rotation under radial load. The greater the number of balls for a given pitch diameter the less this effect.

Under light loads and at high speeds (generally over 24,000 rpm) high-contact-angle bearings can develop an instability due to *gyroscope forces and other dynamic effects*. The ball cannot find true rolling contact with both inner and outer ring simultaneously so that skidding results. Continuous outer ring control is assured by closing outer ring curvatures and vacillation is prevented.

Handling damage causes scratches, nicks, and brinelling, and is one of the greatest sources of vibration trouble. Rust and pitting also can spoil super-fine surfaces. Precautions against all of these spoilers must be maintained by supplier and user alike.

The greatest single source of trouble comes from *dirt*. Foreign matter in the bearing or lubricant can be removed if recognized, but the cleaning cannot revitalize pock-marked races and balls. Therefore, it behooves all bearing manufacturers and users to build the best "clean rooms."

The selection of the *bearing lubricant* has an influence on the vibration level of electric motors. For example, the chart shown in Fig. 9 shows polar plots of torque versus time showing torsional vibration as a function of trace width. The amplitude of vibration varies in a five-to-one ratio between two greases—one a so-called "working" grease, the other a "channelling" type. Notice how the low torque of the "channelling" grease increases momentarily at intervals as a particle of grease drops under the balls to provide lubrication at some rate proportional to changes in local temperature.

The second plot of torque shows a low band or vibration level in a "working" grease. It is possible then to have low torsional vibration and still select the proper mechanical grease action as required by other factors in the application.

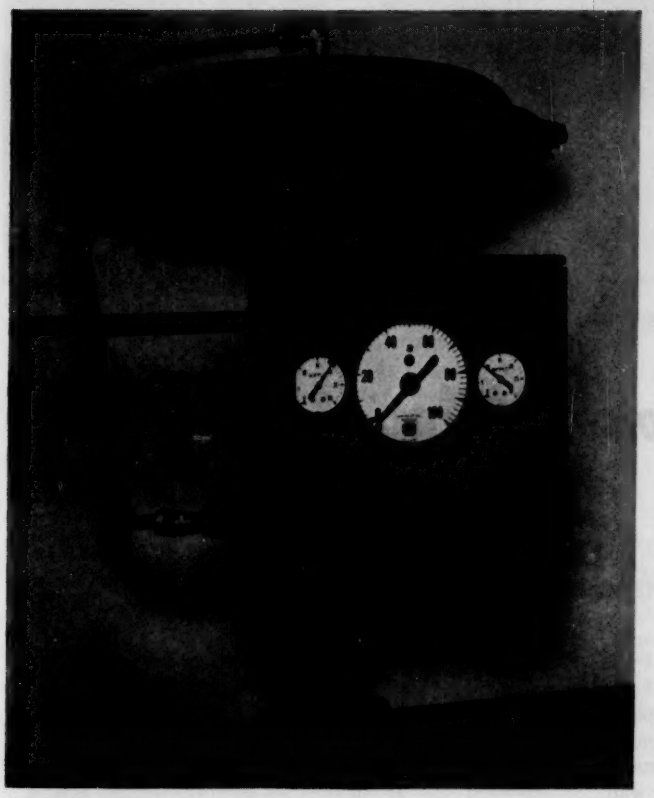
Misalignment Effects

Nearly perfect bearing specimens that pass all vibration tests can become vibration generators in an instrument or motor. Here the responsibility for control of vibration falls to the instrument builder. A small misalignment of the bearing in the apparatus can mysteriously double, triple, and even multiply tenfold the vibration level or the torque level.

Fig. 10A shows the panoramic analysis of a bearing with only a few vibration peaks; B shows the same bearing misaligned slightly.

The magnitudes of error represented are gross compared to the fine precision tolerances that both instrument and bearing companies have otherwise held scrupulously in the individual parts.

New...from United States Gauge!



Wide controller model range. The USG Pilot-Positioner is available with most controller models in the USG Pilot line. These include pressure measurement from 30 in. Hg vacuum to 10,000 psi (applicable to liquid level as well), and temperature measurement from —350F to 1000F. Also, proportional band, adjustable for 0 to 75%, or adjustable differential gap (for fast-stroking valve). Unit measures a compact 8½ in. square.

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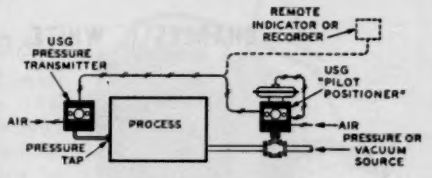
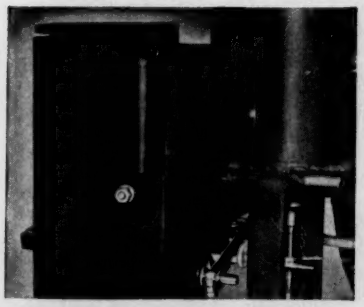
. . . in low-cost, valve-mounted
U.S. Gauge Pilot-Positioner

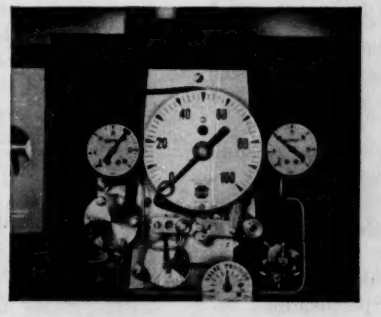
First practical combination of an indicating pneumatic controller and a valve positioner. One compact unit for temperature or pressure control and quick, accurate valve positioning. Check details here. Then send for Bulletin FO29 today!



The unit can have its measuring element directly connected to the process. Or, as shown in diagram, it can be a pneumatic receiver for use with all makes of pneumatic transmitters. This permits additional indicating or recording at a remote panel board, as well as indication of the variable at the valve.



Eliminates second unit! Valve-mounted close to the process, the USG Pilot-Positioner minimizes transmission lags, provides higher precision and speed in valve action. Need for separate valve positioner is eliminated, cutting initial cost of two controls and saving on installation and maintenance. Unit fits any standard diaphragm motor valve.



New non-bleed relay. Faster, more accurate and positive positioning action is assured with a new USG-designed, high capacity non-bleed relay. A control by-pass panel with manual-automatic-service positions is offered as an option, mounting underneath the instrument case. Another option permits remote pneumatic set point adjustment.

Mechanical feedback; one air supply. The new Pilot-Positioner employs mechanical feedback through a lever system. Controller's pneumatic components are used to amplify air pressure. Only one air supply required and pressure can be as high as 65 psi. Adjustable for valve stem travels from ⅜ in. to 4 in. Valves can be air-to-open or air-to-close.

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Measurement of Noise, Vibration, and Shock

CHARLES E. WHITE, AVCO Research and Advanced Development Division

THIRTY YEARS AGO the larger powerful speakers were for the newly-perfected sound movie systems being introduced into important theaters; ear-splitting sounds were generated by twenty-watt speakers arranged in multiple groups. This was the ultimate in noise making.

Recently in one of AVCO's sound isolation chambers (Fig. 1) with ear plugs in place and hands pressed over my ears for further attenuation, I felt a sound pressure equivalent to 155 dbm generated by a single 3000-watt loudspeaker. The loudspeaker art has advanced in thirty years. In fact it advanced astoundingly in five years. This loudspeaker (Fig. 2) reproduces music over the range of 20-5000 cps at such a sound level that fifteen minutes exposure could result in permanent impairment of hearing. Also, it is possible to couple in auxiliary drives to extend the range to 15 kc. This assembly reproduces sound with less acoustical distortion than did the high-fidelity theater system of twenty years ago.

The speaker shown in Fig. 2 provides an acoustical environment to test components. Specifications require exposure to a random noise signal within the range 25-6400 cps with an average sound pressure level equivalent to 150 dbm.

Noise Measurement

As noise intensity has increased, the requirement for measurement instrumentation has increased correspondingly. Between 1950 and 1955, several units appeared on the market capable of measuring intensity levels as high as 200 dbm (Fig. 3). These incorporated ammonium di-hydrogen phosphate crystals within stainless-steel enclosures. Another unit (Fig. 4) is a refinement of the condenser microphone, suitably stiffened to withstand high sound pressure levels.

Vibration Generation

Acoustic noise testing is closely related to vibration testing. The larger and more efficient vibration generators are actually "loudspeakers" and are subject to the loudspeaker's deficiencies when developing large voice-coil movements. Low load-handling capacity, signal shapes restricted to near-sine waves, limited upper-frequency response, and definite limits of amplitude excursions are the order of the day. These elephantine loudspeakers are designed by the trade as *vibrators* or, more commonly, as *shakers*.

Most shakers can be tilted for transverse vibrational tests.

A facility built recently by American Research Co. and installed at AVCO is capable of performing vibrational tests while generating any required environment comprising altitude, temperature, and humidity.

Vibration Measurement

The need to monitor, record and calibrate the excursions of motion generators has brought to market many varieties of accelerometer, velocity pickups, displacement indicators, etc. They include piezoelectric crystals, secondary pickup coils placed within the effective control area of a primary driving coil, capacity-controlled probes, and stroboscopic interferometers.

The outstanding developments in *piezoelectric transducers* during the past ten years were (1) the ADP

crystals and (2) the barium titanate unit, which is now used widely. The barium titanate unit is rugged, resists heat and has reasonable sensitivity. Monitoring pickup coils have been aided somewhat by improved designs in magnet flux distribution employing improved materials. However, this type of pickup is inherently inefficient and inaccurate.

The *capacity-type probe* has shown marked effectiveness in applications at audio frequencies. Some good work has been done with these at the National Bureau of Standards. In addition, conversion of standard capacity microphones to perform the same purpose has been accomplished by the NACA laboratories at Cleveland. Although not suited particularly for large-amplitude displacements, the response to high-frequency vibrations is invaluable.

The *stroboscopic interferometer* developed at the Bureau of Standards also is used to measure small excursions through a frequency range to 20,000 cps with an accuracy close to ±6%.

FIG. 2. LOUDSPEAKER assembly for 3000 watts.

FIG. 3. HIGH-INTENSITY microphone developed by Massa Labs.

FIG. 4. HIGH-INTENSITY microphone and probe developed by Altec Lansing. Probe can be used to 700°C.

Shock

In order to perform shock tests to a scientific and engineering standard, AVCO makes use of various devices with some form of controlled force. One develops impact forces controlled by pellets of molded lead placed on the anvil to receive a dropped carriage and specimen. Molding the pellets is simple and the shock wave form is limited solely by the engineer's molding ability and imagination.

Fig. 5 shows a shock tube used to stimulate tremendous speeds. The instrument consists essentially of a large accumulation of air held under high pressure at one end of a tube by a special membrane. The pressure is raised until the membrane ruptures at a predetermined test pressure, whereupon the air bursts through the length of the tube at speeds up to 25,000 miles per hour.

Special cameras and recorders are stationed at strategic locations along the length of the tube to collect data as the shock wave passes models of nose cones or other structures under study. Fig. 6 shows a rotating mirror camera (right) and rotating drum camera (left) developed and built by AVCO. In the rotating-mirror camera, the image is reflected and swept over fast-emulsion film strips by a hexagonal mirror rotated at high speed by an air turbine drive. The film strips are on a curved path and always in focus, giving a trace which is a true record of position versus time. This camera is particularly adapted to recording hypervelocity phenomena. The rotating-drum camera shown has had use in ballistic, propulsion, combustion, and ignition studies, and in recording shock-tube phenomena using the Schlieren system and multiple spark gaps.

The record tracing speed of the rotating-drum camera is a maximum of 0.19 mm/microsecond. The rotating-mirror camera has a maximum writing speed of 4 mm/microsecond, almost equivalent to 13,000 feet/second.

FIG. 5. SHOCK TUBE.

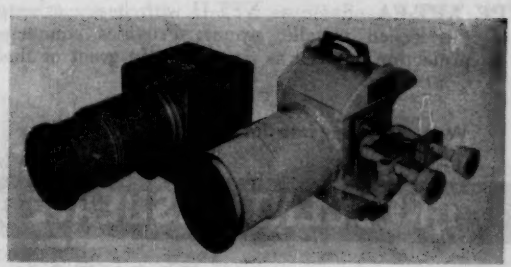

FIG. 6. ROTATING-MIRROR and rotating-drum cameras.

Presented at the Eleventh Annual Convention and Exhibition of the Audio Engineering Society, New York, N. Y.

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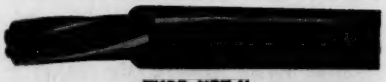
TYPE XPT-F—Same as XPT-U with heavy asbestos braid and outer PVC sheath. Provides time delay in event of flash fire.

TYPE XPT-FA—Same as XPT-U with heavy asbestos braid and interlocked metallic armor. Provides complete mechanical protection, as well as time delay in event of flash fire.

TYPE PA

TYPE PAT

TYPE PT



TYPE XPT-U

TYPE XPT-F

TYPE XPT-FA

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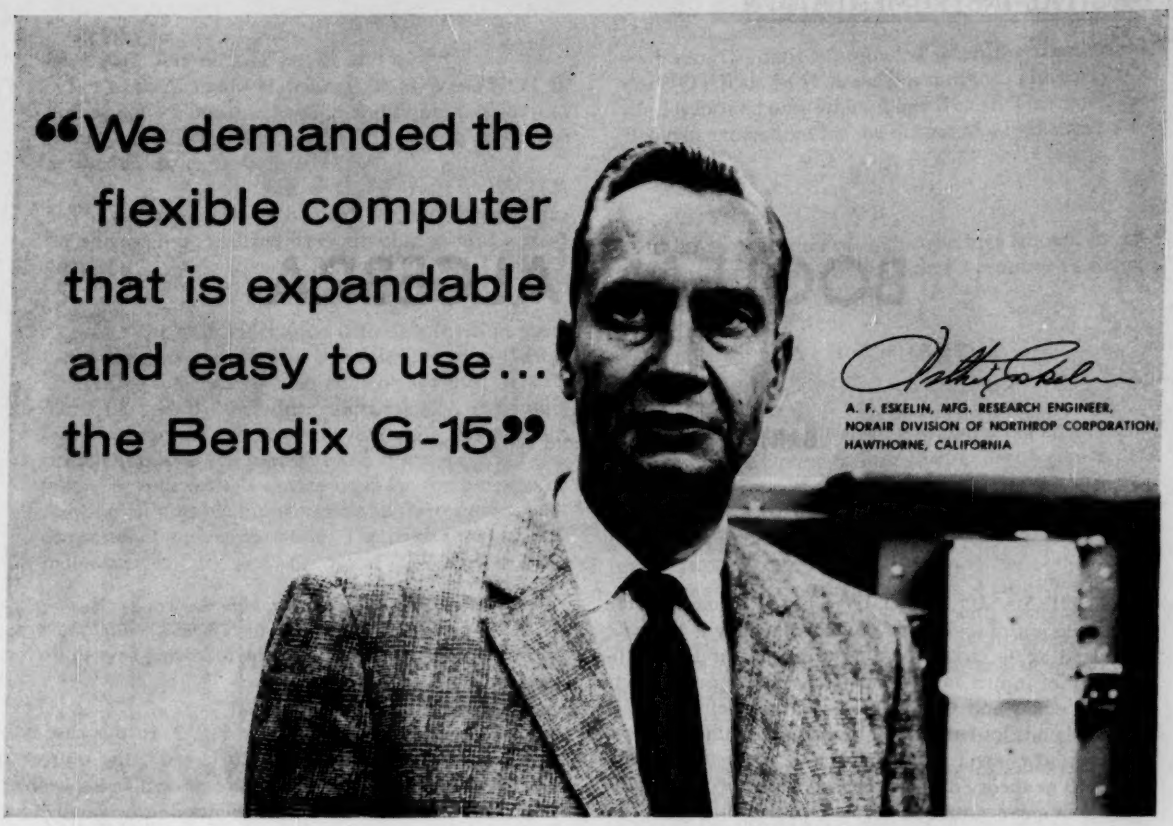

A. F. ESKELIN, MFG. RESEARCH ENGINEER, NORAIR DIVISION OF NORTHROP CORPORATION, HAWTHORNE, CALIFORNIA

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CIRCLE 65 ON READER-SERVICE CARD

BOOLEAN ALGEBRA

GARY A. WIRES, Packard Bell Computer Corp.

THE BASIC BUILDING BLOCK used in the design of logic-type control circuitry is the *gate*, defined as "a circuit having an output and a multiplicity of inputs so designed that the output is energized when and only when a certain definite set of input conditions are met."* Certain arithmetic operations and control functions can be performed by the gate. The theory of gating networks is especially useful with Boolean notation because control functions can be represented in terms of the discrete binary digits 0 and 1. These digits denote the state of many common bistable devices—i.e., non-conduction or conduction, discharged or charged, on or off lights or switches, etc.

Representation of Gates

Fig. 1 shows the symbol of an *and* gate. The gate receives input signals, A, B, . . . N, and generates an output function C only when A *and* B are present. Fig. 1 also shows a switch analogy of the *and* gate; lamp C lights only when A *and* B are closed.

AND functions are also termed *logical multiplication;* a dot is used as its symbol. The following says that A *and* B produce C:

$$A \cdot B = C \qquad (1)$$

The basic *or* gate is shown in Fig. 2. In this case if either A *or* B is present (switch closed), the output exists. *OR* functions sometimes are termed *logical addition;* the most common symbol used is a small v, although a plus sign also is used by some. The following says A *or* B produces C:

$$A \vee B = C \qquad (2)$$

A third basic operation used in Boolean algebra is the inversion, or *not* function (Fig. 3). The symbol is a bar over the function—that is, $\bar{A}$ means that A is not present (0). The *not* function inverts the state of the bistable function—that is, it makes a 1 into a 0, and vice versa.

The logic associated with "except" and "nor" and other logic-type decisions can be built up from the

*Van Nostrand's *Scientific Encyclopedia*

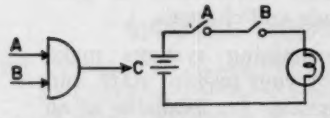

FIG. 1. BASIC *and* gate, symbol and switch analogy.

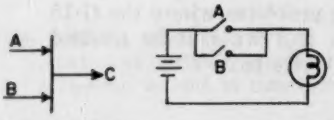

FIG. 2. BASIC *or* gate, symbol and switch analogy.

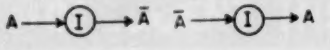

FIG. 3. BASIC *not* symbol is bar over letter.

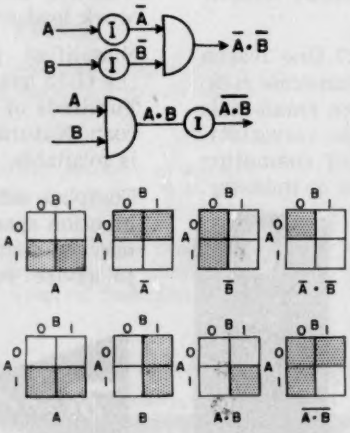

FIG. 4. SYMBOLIC representation of *not* A *and not* B ($\bar{A} \cdot \bar{B}$); also *not* (A and B). Logic charts show that they are not equal.

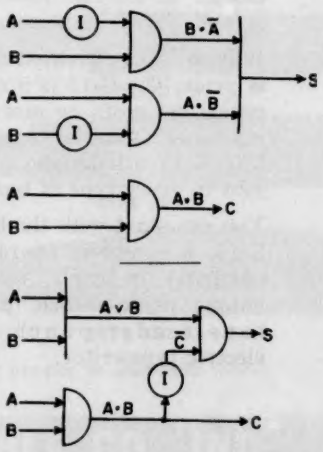

FIG. 5. TWO SCHEMATICS for a half adder; the second, representing equation 5, is the simplest.

basic logic functions of *and*, *or* and *not*.**

Let us consider the statement: NOT A *and* NOT B. Fig. 4 shows a possible hookup and symbol. Note that A and B are inverted to get NOT A *and* NOT B. The mathematical expression is:

$$\bar{A}\cdot\bar{B} = C \qquad (3)$$

The intrinsic value of Boolean techniques and relationships can be realized by examining several typical problems:

Half Adder

Consider the half adder (one with no provision for a carry digit from a previous operation) used in digital computing machinery and control systems. If two digits (A and B) are added algebraically, the result will be a sum (S) and a carry digit (C). All possible combinations of two inputs A and B are shown in the following *truth table*, a device used for the purpose of showing all possible input states and the resultant output states of a given situation. The truth table for the half-adder is:

Input		Output		S exists when	C exists when
A	B	S	C		
0	0	0	0		
0	1	1	0	$\bar{A}\cdot B$	
1	0	1	0	$A\cdot\bar{B}$	
1	1	0	1		$A\cdot B$

**No new sign is really needed for EXCEPT, for it may be expressed easily with AND and NOT. The class of things a EXCEPT b is the same as the class of things which are a AND NOT b.

Nor is a new sign needed for the other OR, OR ELSE, the OR which does exclude both alternatives. For, a OR b BUT NOT BOTH is the same as a OR b EXCEPT BOTH a AND b.

In other words, Boolean algebra is an algebraic technique for handling classes of things with the operations of AND, OR, and NOT. It seems simple, and it is simple. Elementary algebra is really so complicated that the human race required centuries to develop a sufficient good symbolic technique to solve the problems about numbers which confronted it. The subject matter of Boolean algebra is, on the other hand, so simple relatively that men have muddled along for centuries without an algebraic expression for the subject matter. They have used instead a clumsy and very incomplete substitute, the part of formal logic dealing with syllogisms, dating from Aristotle. Because of clumsy tools, mankind has laboriously collected plenty of logical errors. —Excerpt from book *Symbolic Logic and Intelligent Machines*, Edmund C. Berkeley, Reinhold Publishing Co., 1959.

A sum (S) digit is produced when the condition A *and* NOT B, or NOT A *and* B is satisfied. The carry (C) digit is formed only when A *and* B exist. Therefore, the Boolean expressions for the output of a half adder are:

$$S = (\bar{A}\cdot B)\ v\ (A\cdot\bar{B}) \qquad (4)$$

$$C = A\cdot B$$

Another definition of S uses the fact (shown by inspection from the truth table) that S requires existence of either A *or* B, *and* NOT C.

This can be written:

$$S = (A\ v\ B)\cdot\bar{C} = (A\ v\ B)\cdot\overline{(A\cdot B)} \qquad (5)$$

$$C = A\cdot B$$

Expressions 4 and 5 can be drawn schematically to see which is simplest to instrument. Fig. 5 shows the two alternatives, of which the second is the simplest, requiring two *and* gates, one *or* gate, and one inverter, whereas the original required three *and* gates, one *or* gates, two inverters.

Alternative expressions such as 4 and 5 can be developed rapidly when working with complex logic statements simply by applying the thirty-six postulates developed by George Boole, several of which are listed in Table 1.

Boolean Postulates

The Boolean postulates are actually logical operations drawn from the established premises. However, as they are not obvious it is well to examine one or two in detail to see why they are true. A logic chart or Venn diagram can help in visualizing the truth or falsity of the assertions.

The basic postulates that differ from ordinary algebra include the distributive law and the dualization law.

Fig. 6 shows the logic chart for the important inversion postulates, known also as dualization laws, DeMorgan's Theorem, or Involution Law. Note that $\bar{A}\cdot\bar{B}$ does not equal $\overline{A\cdot B}$. An important consequence of the inversion postulate is that each term (A, B, etc.) is inverted, each *or* gate becomes an *and* gate, and each

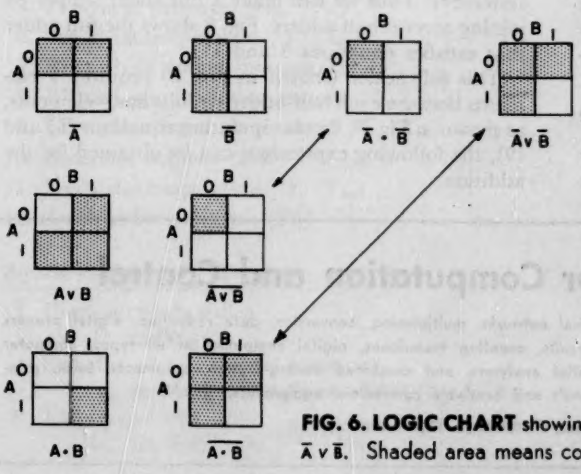

FIG. 6. LOGIC CHART showing that $\bar{A}\cdot\bar{B} = \overline{A\ v\ B}$, and that $\overline{A\cdot B} = \bar{A}\ v\ \bar{B}$. Shaded area means condition is true.

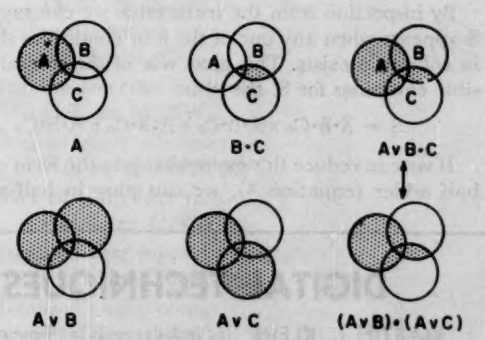

FIG. 7. VENN DIAGRAM showing that $A\ v\ B\cdot C = (A\ v\ B)\cdot(A\ v\ C)$.

TABLE 1—BOOLEAN POSTULATES

$A \vee B = B \vee A$ $A \cdot B = B \cdot A$	Commutative Laws
$A \vee (B \vee C) = (A \vee B) \vee C$ $A \cdot (B \cdot C) = C \cdot (A \cdot B)$	Associative Laws
$A \cdot (B \vee C) = A \cdot B \vee A \cdot C$ $A \vee B \cdot C = (A \vee B) \cdot (A \vee C)$	Distributive Laws
$A \vee A = A$ $A \cdot A = A$	Idempotent Laws
$\overline{A \cdot B} = \bar{A} \vee \bar{B}$ $\overline{A \vee B} = \bar{A} \cdot \bar{B}$	Dualization Laws (DeMorgan's Theorem)
$\overline{(\bar{A})} = A$	Involution Laws

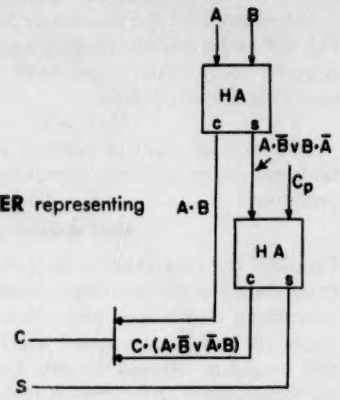

FIG. 8. FULL ADDER representing equations 8 and 11.

and gate becomes an *or* gate. Thus, to invert the expression A v B:

$$\overline{A \vee B} = \bar{A} \cdot \bar{B}$$

The *Venn diagram* for the expression A v B·C is shown at the top in Fig. 7; the diagram for $(A \vee B) \cdot (A \vee C)$ is shown in the same figure. It is obvious that they are equal. This distributive postulate shows that when *or* terms are multiplied, the first terms in each parenthesis are multiplied, as are the second terms, but there is no cross-multiplication. However, one term can be factored out of several *or* terms.

These postulates will now be used to simplify the expressions for a full adder:

Full Adder

A full adder must provide for adding the carry digit (C_p) from the next lowest order. The truth table for this operation is:

Inputs			Output		S exists when	C exists when
A	B	C_p	S	C		
0	0	0	0	0		
0	0	1	1	0	$\bar{A} \cdot \bar{B} \cdot C_p$	
0	1	0	1	0	$\bar{A} \cdot B \cdot \bar{C}_p$	
1	0	0	1	0	$A \cdot \bar{B} \cdot \bar{C}_p$	
0	1	1	0	1		$\bar{A} \cdot B \cdot C_p$
1	0	1	0	1		$A \cdot \bar{B} \cdot C_p$
1	1	0	0	1		$A \cdot B \cdot \bar{C}_p$
1	1	1	1	1	$A \cdot B \cdot C_p$	$A \cdot B \cdot C_p$

By inspection from the truth table we can say that S appears when any one of the four conditions shown in column 6 exists. This gives one of the several possible equations for S, the sum:

$$S = \bar{A} \cdot \bar{B} \cdot C_p \; v \; \bar{A} \cdot B \cdot \bar{C}_p \; v \; A \cdot \bar{B} \cdot \bar{C}_p \; v \; A \cdot B \cdot C_p \qquad (6)$$

If we can reduce this expression into the form of the half adder (equation 4), we can plug in half-adder circuitry. We start by applying the Distributive Law (factoring out of C and $\bar{C}$):

$$S = C_p \cdot (\bar{A} \cdot \bar{B} \; v \; A \cdot B) \vee \bar{C}_p \cdot (A \cdot \bar{B} \; v \; \bar{A} \cdot B) \qquad (7)$$

The second term in parenthesis is in the form of expression (4). The first term can be reduced further by using DeMorgan's Theorem:

$$S = C_p \cdot \overline{(A \cdot \bar{B} \; v \; \bar{A} \cdot B)} \vee \bar{C}_p \cdot (A \cdot \bar{B} \; v \; \bar{A} \cdot B) \qquad (8)$$

Now we have S expressed completely in the form of expression (4). That is, we have two elements—C and the term $(A \cdot \bar{B} \; v \; \bar{A} \cdot B)$. Note that when one is present the other is not because C and $\bar{C}$ can not exist at the same time. Also, the term within each parenthesis is a half-adder sum statement.

Similarly, the following relationship can be derived for the carry (C):

$$C = \bar{A} \cdot B \cdot C \; v \; A \cdot B \cdot C \; v \; A \cdot \bar{B} \cdot C \; v \; A \cdot B \cdot \bar{C} \qquad (9)$$

Applying the Distributive Law:

$$C = (A \cdot B) \cdot (C \; v \; \bar{C}) \; v \; C \cdot (A \cdot \bar{B} \; v \; \bar{A} \cdot B), \qquad (10)$$

C OR NOT C is an unnecessary condition and always equals 1—that is, either C or $\bar{C}$ must always exist. Hence:

$$C = A \cdot B \; v \; C \cdot (A \cdot \bar{B} \; v \; \bar{A} \cdot B) \qquad (11)$$

The parenthesis encloses another half-adder sum statement. Thus we can make a full adder simply by joining several half adders. Fig. 8 shows the full adder that satisfies equations 8 and 11.

This full adder (shown in Fig. 8) requires 9 elements because each half-adder circuits has 4 elements, as shown in Fig. 5. By manipulating equations (6) and (9), the following expressions can be obtained for the addition:

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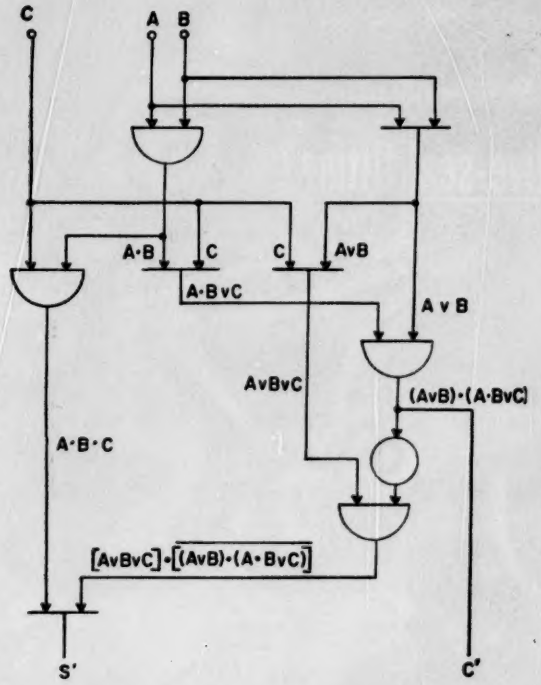

FIG. 9. FULL ADDER representing equation 12.

$$S' = [(A \vee B) \vee C]\cdot[\overline{(A \vee B)\cdot(A\cdot B \vee C)}] \vee A\cdot B\cdot C$$
$$C' = (A \vee B)\cdot(A\cdot B \vee C) \qquad (12)$$

The full adder satisfying this set of equations (Fig. 9) also has nine elements—4 *and* gates, 4 *or* gates and 1 inverter.

Production costs, engineering requirements, design considerations or speed of computation may make one configuration more appealing than another. One other important consideration is the manner in which the previous carry is propagated. It is desirable to hold the number of gates through which the carry must pass to a minimum for high-speed carry propagation. Sometimes the carry signal must be transmitted through two or more gates for synchronization with other operations.

Other configurations of the full adder can be constructed by manipulating equations (6) and (9). Each configuration can have particular merits for a specific application.

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Steam Driven Electric Power Plant
Problem worked out by a Bendix G-15 Computer:

Readings:

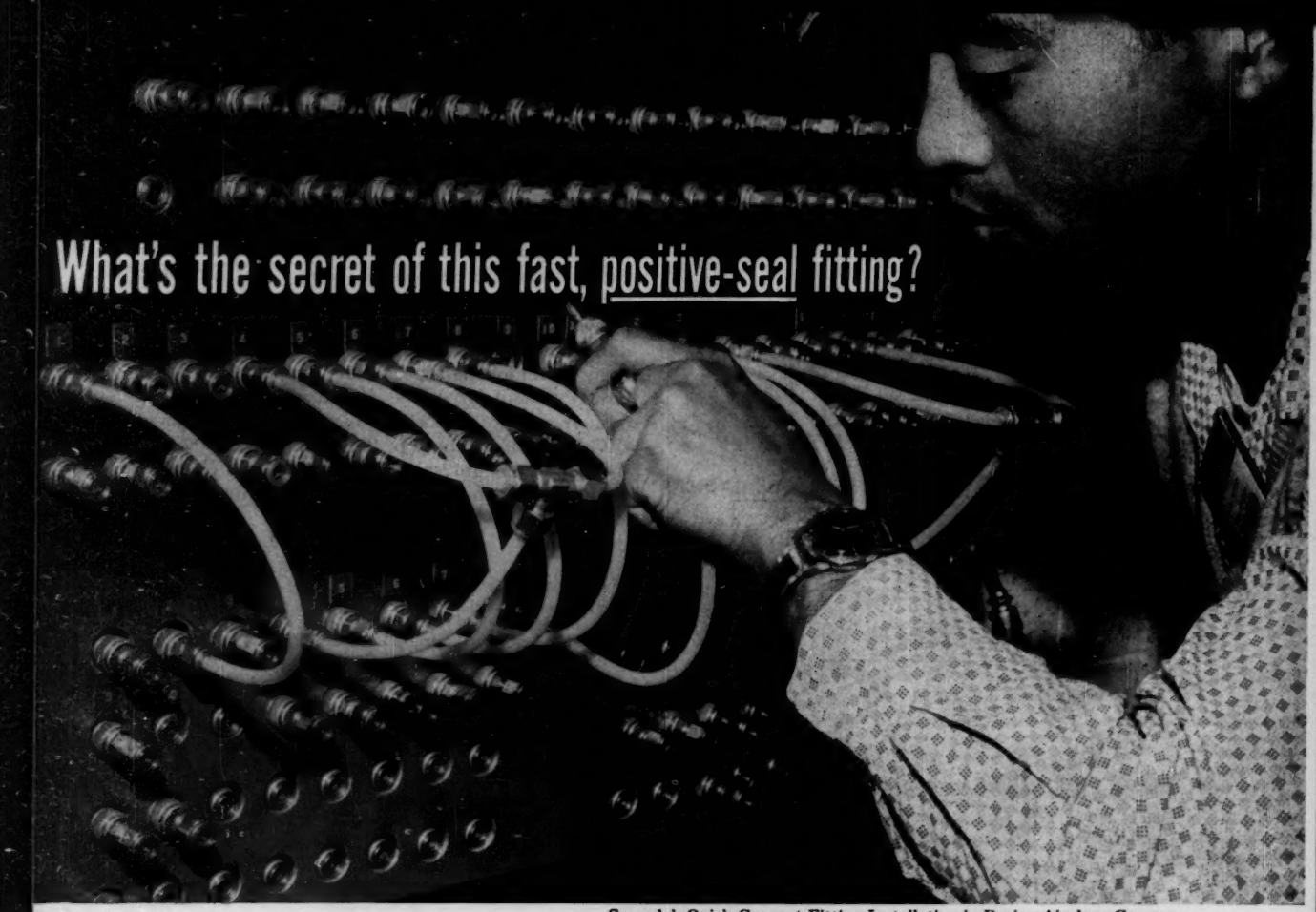
1. Time
2. Fuel input rate, lb/hr, (W_f)
3. Fuel heat content, btu/lb, (q)
4. Total steam output, lb/hr, (W_s)
5. Superheat pressure, psig, (P_{sp})
6. Superheat temperature, °F, (T_{sp})
7. HP turbine output pressure, psi (P_{rh})
8. HP turbine output temperature, °F, (T_{hp})
9. LP turbine input temperature, °F, (T_{rh})
10. Generator output—(KW)
11. Feedwater temperature, °F, (T_{fw})
12. Ambient Pressure, psi, (Pa)

Equations Solved by Computer

1. Heat input into boiler
   $$Q = (W_f)(q)$$
2. Enthalpy of superheated steam
   $$h_{sp} = 941.1 + 0.6\ T_{sp} - 0.034\ (P_{sp} + Pa)$$
3. Enthalpy of feed water
   $$h_{fw} = (0.955)\ (T_{fw})$$
4. Enthalpy of hot reheat steam
   $$h_{rh} = 1004.2 + 0.53 \times T_{rh} - 0.02\ (P_{rh} + Pa)$$
5. Enthalpy of steam leaving HP turbine
   $$h_{hp} = 1001.8 + 0.55 \times T_{hp} - 0.06\ (P_{rh} + Pa)$$
6. Boiler heat output
   $$H_o = W_s\ (h_{sp} + h_{rh} - h_{hp} - h_{fw})$$
7. Boiler efficiency
   $$B.E. = H_o/Q$$
8. Turbine-generator heat rate
   $$H.R. = H_o/KW$$
9. Over-all plant efficiency
   $$P.E. = (3410)\ (KW)/Q$$
10. Over-all plant heat rate
    $$P.H.R. = Q/KW$$
11. Totalized heat input
    $$T.H.I. = \int Q dt,\ Btu$$
12. Totalized power output
    $$T.P.O. = \int (KW) dt,\ Btu$$
13. Average plant efficiency index
    $$A.E.I. = T.P.O./T.H.I.$$

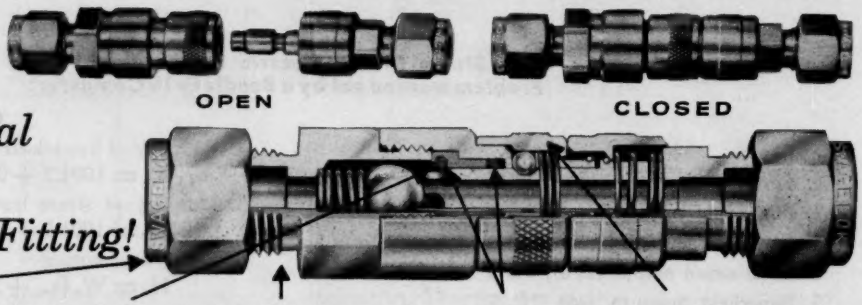
This has been worked out in detail on a G-15 (Bendix) computer.

What's the secret of this fast, positive-seal fitting?



Swagelok Quick-Connect Fitting Installation in Boeing Airplane Company, Seattle, Wash., Test Facilities for Boeing 707 Jet Stratoliner.

Here's the secret of this fast, positive-seal Swagelok Quick-Connect Fitting!



1. Swagelok Quick-Connects with single end or double end shut off for tube to pipe, tube to tube, bulkhead tube to tube applications are available in brass and stainless steel in sizes for ¼" and ⅜" O. D. tubing.

2. Flow resumed instantly and vacuum tight seal assured when connection is made.

3. Light, compact, streamlined design. Occupies little space. For use with portable equipment, and bulkhead or panel applications.

4. Instant-acting seals completely prevent loss of pressure when fitting is disconnected.

5. No twisting, turning or wrench action necessary. Easy straight-line finger tip pull or push action for instant connecting or disconnecting.

In the Boeing Airplane Company photo shown above, the tubes are instrumentation pressure lines running from the large jet engines on test stands to the patch board, where the lines are coupled into measuring devices.

The Boeing Airplane Company adopted this positive Swagelok Quick-Connect Fitting to simplify test installations, and substantially cut down test set-up time. Both ends of the many pressure lines are Swagelok-equipped. Previously, engineers used a screw-type fitting which required a wrench and valuable time-consuming operations to tighten and remove.

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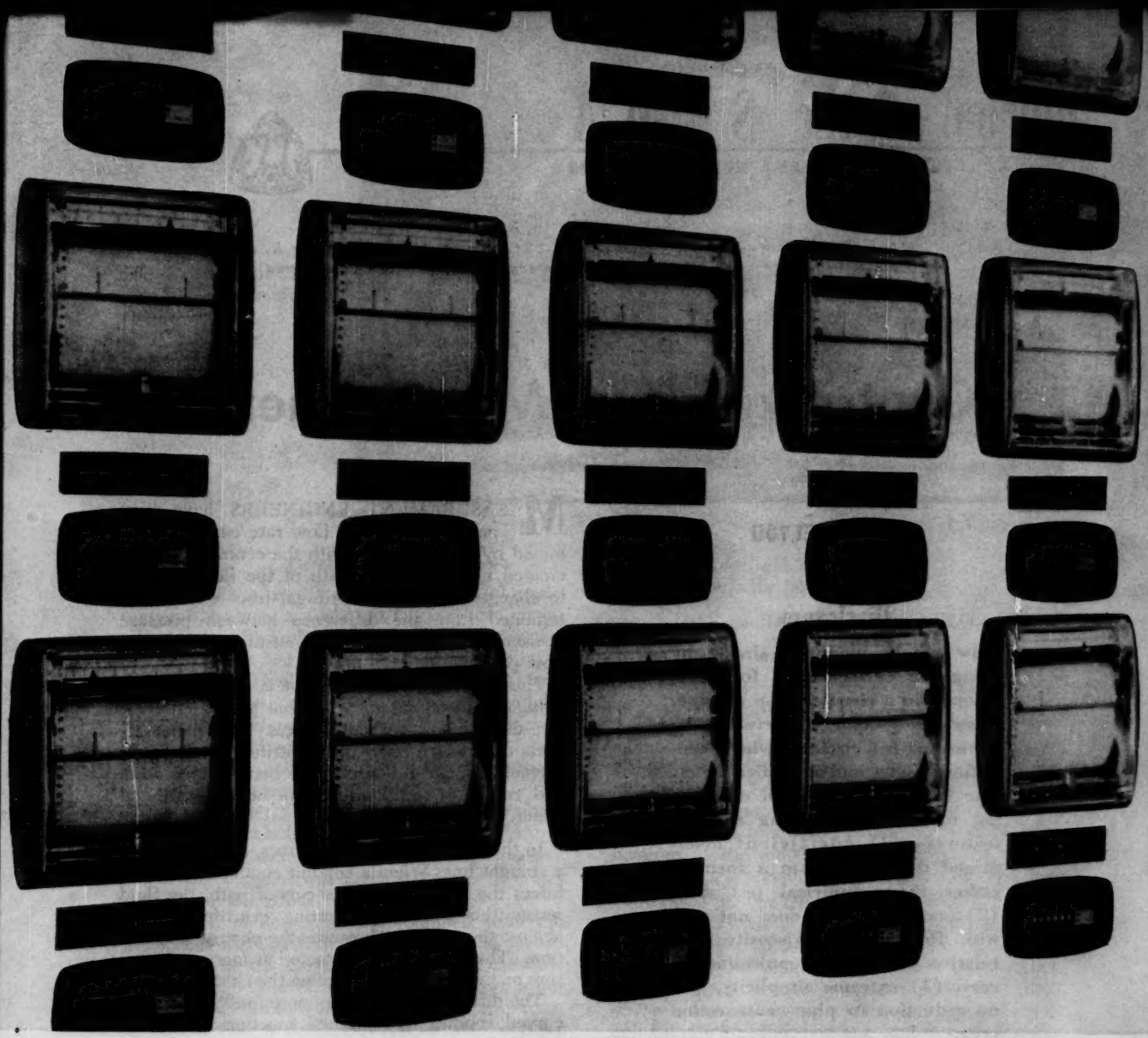


On this centralized Foxboro panel, Type 14A Integrators provide continuous totalizing of significant process and plant service flows – recorders give trend records required by operating personnel.

Simplest way to get continuous, accurate totalizing

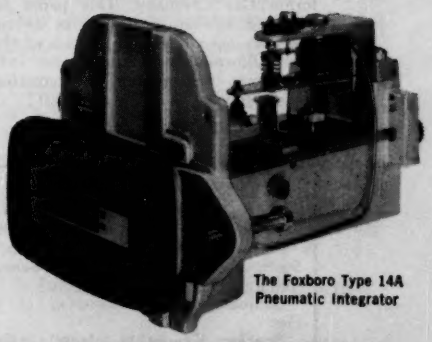
of all process and plant service flows

For automatic flow-accounting of all process and plant service fluids, Foxboro Type 14A Pneumatic Integrators offer unparalleled advantages of accuracy, convenience, and economy.

Easily connected to signal lines from new or existing Foxboro d/p Cell* Flow Transmitters, 14A Integrators provide **continuous** totalizing of significant flows. They can be mounted with the d/p Cell at the point of measurement, or panel-mounted hundreds of feet away.

The square root function is automatically extracted — flow totals are read directly. A simple, inherently accurate, centrifugal force system eliminates the errors of cams, special chambers, linkages, and intermittent counting.

Bulletin 13-23 fully illustrates and describes the Type 14A Pneumatic Integrator, and points the way to economical accounting of process and plant service flows. Write for your copy today. **The Foxboro Company, 462 Neponset Ave., Foxboro, Mass.**



The Foxboro Type 14A Pneumatic Integrator

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CIRCLE 67 ON READER-SERVICE CARD

Journal of the S C M A . . .
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Centrifugal Flow Measurement

J. T. CORTELYOU

Disclosure

Flow can be measured simply by using the centrifugal force developed in a circular loop of pipe. Here is a comparison between the promising full circle pipe-bend centrifugal meter and an orifice meter. The full-circle pipe-bend centrifugal meter has following exciting features—(1) coefficient determined directly from a formula rather than empirical test data, (2) coefficient that does not vary with flow rate or viscosity, (3) relative immunity to pulsation errors, (4) extreme simplicity, (5) no reduction in pipe cross-section area.

Presented before the Southern California Meter Association, November 19, 1959.

Mr. Cortelyou is employed as Standards Engineer, Engineering Department, Southern California Gas Company. This paper has been prepared by Mr. Cortelyou as an individual and does not reflect the policies of the Southern California Gas Company nor indicate its acceptance or rejection of centrifugal flow measurement.

March Meeting

Date: Thursday Evening, March 17, 1960
Time: Dinner 6:30 p.m., Meeting 8:00 p.m.
Place: Rio Hondo Country Club, 10627 South Old River School Road, Downey, California
Subject: Mass Flowmetering of Natural Gas
Speaker: Charles M. Halsell, Project Supervisor, Black, Sivalls and Bryson, Inc.

MEASUREMENT ENGINEERS have long realized that fluid flow rate can be determined by its correlation with the centrifugal force created by causing the path of the flowing fluid to change direction. Centrifugal force can be determined from the difference between pressure measured on the inside and outside of a curved flow path.

This method of measurement is known as *centrifugal flow measurement* and has been tried using 90° elbows, but without success. This paper reports tests which show that centrifugal flow measurement using a full-circle pipe bend is successful, and compares a full-circle pipe-bend centrifugal meter with an orifice meter.

In the absence of external forces, a fluid flows in a straight line. When a conduit conducting a fluid forces the fluid to follow a curved path, the fluid resists this action by exerting centrifugal force against the wall which causes the change in direction. This force can be detected as increased pressure on the conduit wall forcing the change of path.

The difference of pressure on opposite sides of a curved conduit is a definite function of density, velocity, and radius of curvature. Velocity can be converted to flow rate by multiplying it by the cross-sectional area of the conduit.

History

The American Society of Mechanical Engineers' treatise on fluid flow measurement, *Fluid Meters, Their Theory and Application*, refers to this method of measurement under the subject of "Elbow Meters" in each edition since its first in 1924. *ASME Transactions*, volume 36, 1914, page 326 described this type of measurement using 90° elbows.

Patents 970,965 issued in 1910 and 1,181,490 in 1916 both covered the use of 90° elbows for measurement of fluid flow. The first patent disclosed an empirical formula for determining flow rate, and the second patent presented the correct theoretical formula. W. M. Lansford described his use of 90° elbows for the measurement of flow of water in the University of Illinois Experiment Station Bulletin Number 289 in 1936.

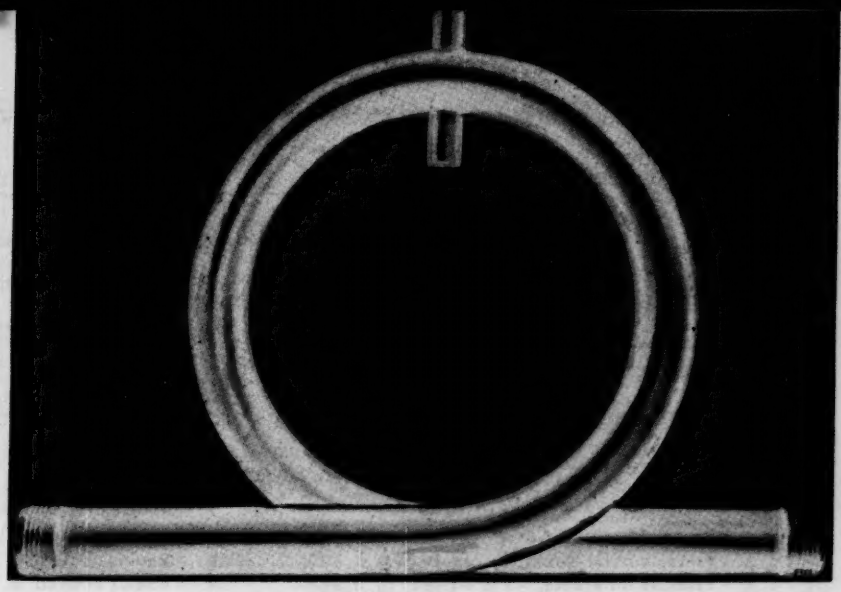


FIG. 1. FULL-CIRCLE pipe-bend centrifugal meter.

Circle Bend

Although the centrifugal flow method of measurement has been available, it has not been generally employed. Probably the reason for nonacceptance is the fact that it has been tried only by the use of a 90° elbow, which has inherent error and inconvenience of piping a meter with the inlet and outlet in different directions. (It will be shown in a subsequent section that a 90° elbow is inherently inaccurate and cannot be expected to provide satisfactory measurement.)

The writer felt that, despite lack of satisfaction with elbows, centrifugal flow technique could provide a simple, accurate and relatively inexpensive flowmeter. Thought was given to means of creating a useful centrifugal flowmeter.

Inasmuch as flow rate is determined from the effect of centrifugal force, the radius of the curved flow path and the cross sectional area of the flow stream must be determined accurately. Also, a device in which the flowing fluid will obtain uniform curvilinear flow is needed. A full circle pipe bend (Fig. 1) was selected for experiment.

The inside radius of the pipe and the radius of bend of the centerline of the pipe at the point of differential pressure sensing can be determined accurately by means of a micrometer and ultrasonic thickness gauge. The differential-pressure sensing point can be located far enough downstream of the point where the fluid starts to assume curvilinear flow so that uniform curvilinear flow is realized at the point of measurement. The inlet and outlet of the meter will be essentially in a straight line, offset by only one pipe diameter.

Theory and Formula

Newton's laws of motion show that centrifugal force is a function of mass velocity and radius of curvature. Fig. 2 shows the derivation of the basic centrifugal-flow formula for a liquid (Q_L) and a gas (Q_G). It shows that flow rate depends on size of pipe and bend, the differential pressure between the inside and outside of the bend, and the density of the flowing fluid.

The formula for liquids is:

$$Q_L = (11.34)(r^2)\sqrt{R/r}\sqrt{h}\sqrt{1/S}$$

The formula for gases is:

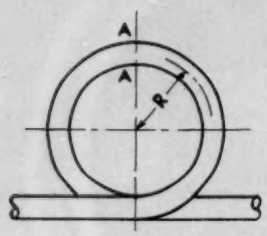
$$Q_G = (676.4)(r^2)\sqrt{R/r}\sqrt{hP}\sqrt{1/G}\sqrt{520/T}\sqrt{Y}$$

The formula for gas is derived using the same value of physical constants used by the American Gas Association in their Gas Measurement Committee Report Number 3, and by the California Natural Gasoline Association in Bulletin TS-561. A standard cubic foot of gas is defined by these publications as the amount of gas contained in one cubic foot at a pressure of 14.73 psia and a temperature of 60°F. The factors $\sqrt{1/G}$, $\sqrt{520/T}$, and $\sqrt{Y}$ are the gravity, temperature, and superexpansibility factors as given in these references.

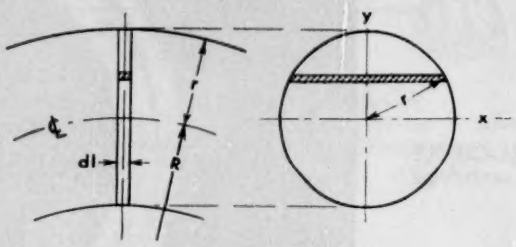
A commercial pipe bend will have an elliptical rather than a circular cross-section at the point of measurement because, even when pipe is heated and filled with sand, bending causes some flattening. Studies show that the basic formulae still apply if the product of the major and minor semi-axes are substituted for r^2, and the minor semi-axis substituted for r in $\sqrt{R/r}$.

The derivation shown in Fig. 2 assumes that the density of the flowing fluid is uniform at all points in the flow stream. This assumption is not true for compressible fluids whose density varies with pressure. The term $\frac{gh'}{w}$ becomes $\frac{gP'}{w} \log \frac{P'+h'}{P'}$ if P′ is taken as the pressure existing at the inside pressure tap; and becomes $\frac{gP'}{w} \log \frac{P'+h'/2}{P'-h'/2}$ if P′ is taken as the average of the pressures measured at the inside and outside pressure taps.

DERIVATION OF CENTRIFUGAL FLOW FORMULA



CENTRIFUGAL METER



SECTION A—A ENLARGED

NOMENCLATURE

p' = Pressure at $y = -r'$, lbs./sq. ft. abs.
P = Pressure at $y = -r'$, psia
p = Pressure at any point, lbs./sq. ft. abs.
h' = Pressure difference, $-r'$ to $+r'$, lbs./sq. ft. abs.
h = Pressure difference, $-r'$ to $+r'$, in.w.c.
w = Density of fluid, lbs./cu. ft.
g = Acceleration of gravity, ft./sec./sec.
V = Velocity at $\mathbb{C}$, ft./sec.
v = Velocity at any point, ft./sec.
l = Length of curve, ft.
r' = Radius of conduit, ft.
r = Radius of conduit, in.
R' = Radius of bend, ft.
R = Radius of bend, in.
Q_L = Flow rate of liquid, gal./min.
Q_G = Flow rate of gas, cu. ft./hr.
S = Specific gravity of liquid, water = 1.000
G = Specific gravity of gas, air = 1.000
T = Temperature of flowing fluid, °F abs.
Y = Deviation from Boyle's Law, ratio

Consider forces on element of fluid shown above.

Increased force on top = Centrifugal force

$$dp \times dl \times 2x = dl \times 2x \times dy \times \frac{w}{g} \times \frac{v^2}{R'+y}$$

$$v = V \times \frac{R'+y}{R'}$$

$$\frac{g}{w} \times dp = \frac{V^2}{R'^2} \times (R'+y) \times dy$$

Integrate over cross section to get total forces.

$$\frac{g}{w}\int_{p'}^{p'+h'} dp = \frac{V^2}{R'^2}\int_{-r'}^{+r'} (R'+y)\,dy$$

$$\frac{gh'}{w} = \frac{2V^2 r'}{R'}$$

$$V = \sqrt{\frac{gh'R'}{2wr'}}$$

Flow, cu.ft./sec. = Area, sq.ft. × Velocity, ft./sec.
(Change units to those used in commercial practice)

For liquid $$\frac{Q_L \times 0.1337}{60} = \pi \frac{r^2}{144}\sqrt{\frac{32.17 \times h \times 5.198 \times R/12}{2 \times 62.37 \times S \times r/12}}$$

$$Q_L = 11.34 r^2 \sqrt{\frac{R}{r}}\sqrt{\frac{1}{S}}\sqrt{h} \text{ gal./min.}$$

For gas $$\frac{Q_G}{3600} \times \frac{14.73}{P} \times \frac{T}{520} \times \frac{1}{Y} = \pi \frac{r^2}{144}\sqrt{\frac{32.17 \times h \times 5.198 \times R/12}{2 \times 0.08073 \times P/14.70 \times G \times 492/T \times Y \times r/12}}$$

$$Q_G = 676.4 r^2 \sqrt{\frac{R}{r}}\sqrt{hP}\sqrt{\frac{1}{G}}\sqrt{\frac{520}{T}}\sqrt{Y} \quad \text{cu.ft./hr.}$$

TABLE 1—COMPARISON OF ORIFICE METER AND CENTRIFUGAL METER, MEASURING AIR FLOW

Test No.	Orifice Meter Coeff.	h "w. c.	P psia	$\sqrt{hP}$	Q_1 (Reference) Cu Ft/Hr	Centrifugal Meter 1" Steel Pipe, 6" Diameter Bend Coeff.	h "w. c.	p* psia	$\sqrt{hP}$	Q_2 (Calculated) Cu Ft/Hr	% Error Q_2/Q_1
1	474.4	17.95	53.5	30.98	14,700	426.0	22.65	51.3	34.09	14,520	−1.2
2	474.4	10.95	53.8	24.27	11,510	426.0	13.70	52.5	26.82	11,430	−0.7
3	474.4	3.90	54.3	14.55	6,900	426.0	4.85	53.8	16.15	6,880	−0.3
4	474.0	18.15	74.6	36.80	17,440	426.0	22.55	72.4	40.41	17,210	−1.3
5	474.4	10.30	74.8	27.76	13,170	426.0	12.75	73.6	30.63	13,050	−0.9
6	474.9	2.25	75.0	12.99	6,170	426.0	2.80	74.7	14.46	6,160	−0.2
7	474.0	18.25	105.3	43.83	20,780	426.0	22.75	103.1	48.43	20,630	−0.7
8	474.0	9.00	105.6	30.83	14,610	426.0	11.20	104.5	34.21	14,570	−0.3
9	473.9	2.50	105.3	16.23	7,690	426.0	3.10	105.0	18.04	7,690	0.0
						*Average of pressures indicated at inside and outside pressure taps.					−0.6 (average)

TABLE 2—CENTRIFUGAL METER FLOW TEST WITH WATER

¾" Stainless Steel Tubing, 7" Diameter Bend

Test No.	Centrifugal Meter Location Pressure Taps, °	Coeff.	h* "w. c.	$\sqrt{h}$	Q_1 Calc. gal/min	Weighing Tank Weight lbs	Time (min)	Q_2 Test gal/min	% Error (Q_1/Q_2)
1	45	5.954	6.458	2.541	15.13	131.75	1	15.80	−4.2
	90	5.908	7.339	2.709	16.00	131.75	1	15.80	+1.3
	180	5.890	7.244	2.692	15.85	131.75	1	15.80	+0.3
2	45	5.954	3.615	1.901	11.32	100.00	1	11.99	−5.6
	90	5.908	4.306	2.075	12.26	100.00	1	11.99	+2.2
	180	5.890	4.211	2.052	12.08	100.00	1	11.99	+0.7

*Used Meriam #3 Manometer Fluid, Sp. Gr. = 2.95. Converted this reading to inches water column. Correction made for weight of water over Manometer Fluid.

Investigation shows that the assumption will not cause an error of more than 0.1% if the ratio of differential pressure to total absolute pressure is kept below 0.4% when pressure is measured at the inside pressure tap, or 15% when pressure is taken as the average of those measured at the inside and outside pressure taps. However, neither of these restrictions impose a serious limitation on the commercial measurement of compressible fluids with a centrifugal meter. When a large differential is necessary, or where extreme accuracy is desired, it will be desirable to compute and use the pressure existing at the center of the flow stream.

An average velocity is used in deriving the flow formula rather than considering the actual velocity at each point in the flow stream. Study shows that this makes no difference in the flow formula.

Proof

Proof of the validity of the formulae and the assumption that the curved path must be much greater than 90° has been obtained in several tests.

A test was made with a 6" full-circle pipe bend of 1" steel pipe measuring air from a standard 3" orifice meter. Flow rate indicated by the orifice meter was assumed correct and used as a reference (Table 1).

This test demonstrates the accuracy (0.6%) of a centrifugal meter for measurement of compressible fluids. It may be noted that the formula for the centrifugal meter does not require the use of a coefficient based on flow rate, viscosity, and test data.

A 7" diameter bend of ¾" stainless-steel tubing was tested by flowing water through the meter into a weighing tank in the University of California at Los Angeles Hydraulics Laboratory. This meter was equipped with pressure taps at 45°, 90°, and 180° from the meter inlet to determine the relative accuracy of elbows and circle bends as well as to prove the accuracy of the full-circle bend (Table 2).

Table 2 shows that the accuracy of the full-circle bend is 0.5% and demonstrates its worth for liquid flow measurement. It also can be seen that while the full-circle bend is accurate within the accuracy limits of the test equipment and instruments used to determine the dimensions of the meter, the 90° elbow with pressure taps at 45° is only accurate to about 5% and cannot be expected to provide satisfactory measurement.

After study of the fabrication and test conditions, it is the writer's conclusion that the results obtained from the theoretically derived formula are accurate without need of correction by an experimentally determined coefficient. The error indicated in the proof tests arises from inability to determine the dimensions of the bend, differential pressure, and fluid density more accurately. For example, the inside diameter of a 1¾" bend must be known to within 0.001" to provide flow accuracy of 0.1%. An ultrasonic thickness gage could measure the diameter to this accuracy.

Pulsation

Pulsation is a serious problem in flow measurement. The term "pulsation" is often misused. A fluctuating flow rate, such as is often found in the fuel line to a boiler with snap-action controls, is not true pulsation. A perfect flowmeter would record such flow as a fluctuating record, with complete accuracy.

However, the flow rate from reciprocating com-

pressors is usually essentially uniform but the *pressure* fluctuates rapidly. This is true pulsation which causes considerable and unpredictable errors in flow measurement.

A 6″ bend in 1″ steel pipe was installed in the line receiving the discharge from the cylinder of an air compressor. The *flow* was known to fluctuate. The differential pressure indicated by the centrifugal meter fluctuated with the same frequency.

The meter then was installed on the piping between a similar compressor and its receiver so that it could pass air to the atmosphere. A valve on the outlet of the centrifugal meter was opened to permit what appeared to be a *constant flow rate.* A bourdon-tube pressure gauge connected to the meter indicated a pressure of about 110 psi, which fluctuated rapidly within limits of 1½ psi. During this time the meter indicated a constant differential pressure of 4″ water column.

This test indicates that a centrifugal meter might be relatively immune to pulsation errors. This seems reasonable because a centrifugal meter senses differential pressure at one point along the flowing stream. The differential should be the same whether the pressure is temporarily high or low at that point at the moment. On the other hand, an orifice meter senses differential pressure between two different points along the flow stream. Hence a temporarily higher pressure at one end of the points could be added or subtracted to the differential caused by flow through the orifice.

Additional experiments are planned to study this phenomenon.

Piping

Orifice meters require straight piping or straightening vanes ahead of the orifice to provide uniform flow into the orifice. The centrifugal meter also requires similar protection.

A bend was made with offsets in the inlet and outlet in a plane normal to the bend so that the inlet and outlet centerlines were in the same straight line. Tests showed that the accuracy of this meter was impaired. Meters which produce accurate test results have straight tangents on the inlet of at least two bend diameters. Until further tests are made, it may be assumed that a tangent of two bend diameters is required on the inlet.

Pressure Drop

During the proof tests using air, additional pressure differential readings were taken between the inlet and outlet of the meter. This pressure drop and flow data was compared with the calculated pressure drop for the same length of straight pipe of the same size and found to be essentially equal. It may be assumed that the pressure drop through a centrifugal meter will be approximately equal to what might be expected through the same length of equal-size straight pipe.

Viscosity

There has been no opportunity to test the centrifugal meter with highly viscous fluids, such as heavy oils. However, the meter has been tested with both water and air, which have different viscosities, and accurate results were realized with each. As the flow formula does not involve viscosity, the writer believes the centrifugal meter is independent of viscosity.

Accuracy Range

Like the orifice meter, the centrifugal meter relates flow rate to the square root of the differential pressure. This limits the range of flow rates than can be measured accurately with a given meter equipped with one conventional gage to about 3½ to 1.

Unlike the orifice meter, in which a part of the meter (the orifice) can be changed to accommodate a changed flow rate, additional centrifugal meters must be provided if there is a substantial change in the flow rate. However, centrifugal meters might be so inexpensive that two or more centrifugal meters could be used in parallel or meters could be replaced when the flow rate exceeds the accuracy range of the centrifugal meter in service.

Meter Size

Examination of flow coefficients for both orifice and centrifugal meters show that generally a 1″ centrifugal meter has the same capacity as a 3″ orifice meter. A 1″ centrifugal meter is about 1½′ in length, while a 3″ orifice meter is about 6′ long. In many installations, this space economy should be a great advantage.

Maintenance

Whereas an orifice meter requires regular inspection of the orifice plate to see that it is clean and the edge is sharp, and the orifice meter run must be checked occasionally to be sure dirt and foreign material have not collected behind the orifice plate, the centrifugal meter will not require this type of maintenance and should be able to measure slurries which require segmental orifices in orifice meters.

Acknowledgements

The writer wishes to acknowledge the help of those who made this work possible. The University of California at Los Angeles permitted the use of their Hydraulics Laboratory at cost under their Service-to-Industry Program.

The L. J. Cannon Manufacturing Company of Placentia, California financed the cost of this investigation.

In order to protect this investment, the writer has made a patent search and applied for a patent on the centrifugal meter described. As this device was conceived during the course of the writer's employment with the Southern California Gas Company, shop rights have been retained by them. An exclusive license to manufacture and sell the meter has been given to the L. J. Cannon Manufacturing Company.

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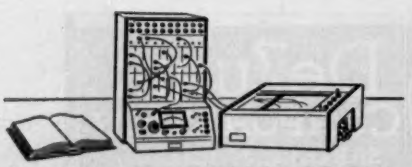

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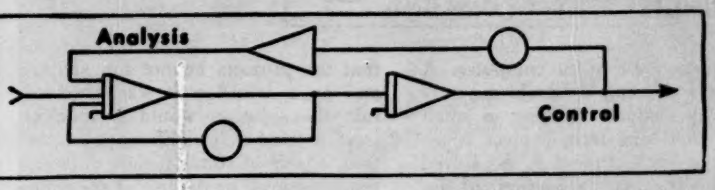
The SIMULATION COUNCIL Newsletter



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Bits

This month we give to you what info we have available on the Southeastern Simulation Council meeting held on October 2 at the University of Alabama, and notes on one paper and the text of another presented at the 14 December '59 meeting of the Eastern Simulation Council meeting at Leeds & Northrup—more would be too much.*

The Southeastern Simulation Council material consists of a brief description of a U of A course on the applications of electronic analog computers by *W. B. Stiles*, an abstract of "Some Engineering Aspects of Low-Frequency Noise Measurements" by *R. S. Johnson* and *J. L. Hammond*, and an abstract of "Loop-Gain Analysis for Implicit Function Generation" by *J. H. Meeks* and *R. S. Johnson*.

The Eastern SC offerings are "Notes for Simulation of Industrial Process Controllers" by *R. L. Farrenkopf* and *F. A. Lapinski*, and "Idealized versus Realistic Simulation of Cascaded Process Lags" by *Morton J. Hausner*.

Pieces

SOUTHEASTERN S/C MEETING OF 2 OCT ON COMPUTER COURSE, NOISE, AND FUNCTION GENERATION

At the 2 October 1959 meeting of the Southeastern Council held at the University of Alabama, *Dr. W. B. Stiles* discussed some computer courses offered at the University. And as we all are (or should be) interested in what our educational institutions are teaching to the future engineers and scientists about computers and simulation, we give you here a summary of Dr. Stiles remarks:

*For me, anyway—Ed.

Stiles on Analog Computer Course

The Departments of Mathematics and Commerce at the University of Alabama offer courses on numerical analysis and programming for digital computers. However, the following discussion is limited to applications of electronic analog computers, and to a description of a course on such applications which is taught in the Department of Engineering Mechanics. **Such computers are used to solve electric circuit problems, electromagnetic and electrostatic problems, control problems, heat-flow problems, problems of vibration, chemical rate process problems, and many other applications in the field of applied engineering in which it is necessary to solve linear or nonlinear differential equations.**

The Department of Engineering Mechanics acquired a small Donner computer for use in instruction, with the thought that it could be expanded for research applications as the need developed. In addition to the basic Donner computer, an electronic function generator was obtained. Since the original equipment was purchased an additional function generator, a function multiplier, and other miscellaneous components have been ordered. A graduate student in the Department of Industrial Engineering constructed a Heath analog computer which was later made available to the Mechanics Department for instructional purposes.

Dr. Stiles said that he hoped only a few students, maybe four or five, would take the course the first time it was offered. Instead 11 students enrolled! This made it difficult to schedule laboratory problems on the single available computer. Interest has continued to grow, and 18 students are enrolled during the current semester.

About 80% of the course time is spent on theory and solving academic

to laboratory use of the computer. A number of simple problems are solved by students working in small squads, and one term project is assigned to each student to be solved individually. An indication of interest exhibited by the class is the fact that near end of the term students have asked to be allowed to use the computer evenings and weekends in order to have sufficient time to complete the problems.

Laboratory problems consisted of the following:

1. Demonstration of coupled vibrations with four degrees of freedom and with variable damping. General precautions to be observed were pointed out at this time.

2. A problem with a single degree of freedom involving an elastic spring and viscous damping together with a disturbing force which varied linearly with time. Many of the examples used in laboratory and recitation involved dynamics problems because this course and a course in differential equations were required of all students.

3. Generation of analytic functions and the use of complex impedances. Various analytic functions, such as

$$y = A \sin (5t + \tfrac{1}{3})$$
$$y = 0.5e^{-0.15}$$
$$y = e^{-10t} \sin 5t$$
$$y = 5 (1 - 2^{-0.25})$$

were set up without the use of the function generator.

In addition to these analytic functions, the students used complex impedances in the input and feed back circuits so that a single amplifier could be used to solve higher-order differential equations.

4. The use of diodes. The simulation of dry friction, dead space, step functions, and limiting operations was studied.

5. Electronic function generator. The function generator was used to solve the problem of large oscillations of a simple pendulum in which the approximation $\sin t = t$ is not justified.

6. Electronic function multiplier. An example in which the resisting force varies as the square of the velocity will be given.

7. Term project. Each student prepared a term project involving some problem with which he was familiar either from other courses or from experience on a job. It was required that the projects be not too simple, and as a criterion it was expected that the solution would include at least a third-order differential equation, a pair of simultaneous differential equations, or the use of the function generator. The projects involved vibration problems, control problems, an electrical oscillator, a problem on rate of variation of concentrations in chemical engineering, and one additional electrical engineering problem requiring the use of a function generator to indicate the output of an electronic circuit.

Dr. Stiles expressed himself as well pleased with response to the course during the first semester and believes the course will improve each time it is offered.

* * *

Next speaker on the program was *D. N. O'Steen* (University of Alabama) who told about their B-58 Cockpit Simulator. (His paper hasn't been released for publication, so we'll say no more about it.)

Meeks on Implicit Function Generation

Following a coffee break *J. H. Meeks* (Georgia Institute of Technology, Atlanta, Ga.) was scheduled for a talk on "Loop Gain Analysis for Implicit Function Generation".* We are indebted to *Ray Lawrence* (Army Ballistic Missile Agency, Huntsville, Ala.), Secretary-Treasurer for the Southeastern SC, for forwarding the following abstract:

John Meeks described a method of steady-state gain analysis useful in programming implicit function generators on the analog computer. The method involves diagramming the circuit in a conical form and then, by means of a fixed set of rules, deriving a quantity termed "tracking gain" which depends on the functional derivatives of the forward and feedback loops. The algebraic sign of the tracking gain indicates the position of stable equilibrium in terms of the input and output variables. It was noted that in the generation of inverse functions by the usual methods, it is difficult to predict the stable point if the inverse function is multivalued or if the feedback involves a number of nonlinear paths.

In addition to the stability information, the tracking gain also provides a measure of the circuit's ability to follow varying input quantities: A large magnitude indicates good tracking ability, whereas smaller values lead to poorer performance. As the tracking gain is normally a function of the input and output variables, the form of automatic gain control required is usually suggested by the nature of this function.

Several applications of the method were presented. The examples included analyses of polar-mode resolvers, square-root circuits, and division circuits.

M. E. McKoy (Glenn Martin Co., Orlando, Florida) suggested that the technique might also be applicable to algebraic programming.

*Prepared in collaboration with his colleague, *R. S. Johnson.*

Johnson on Low-Frequency Noise Measurement

Another speaker on the program was Robert S. Johnson (Georgia Institute of Technology, Atlanta, Ga.), whose talk on "Some Engineering Aspects of Low-Frequency Noise Measurements"* is given here in abstract form.

Bob gave a brief résumé of the application of the analog computer to the measurement of statistical parameters of very-low-frequency noise signals. Particular emphasis was placed on the estimation of variance, amplitude probability distribution, and power spectral density functions.

A simple combination of comparators and integrators was shown to suffice for the estimation of amplitude probability distributions. The circuit for the measurement of a single point on the distribution curve requires, at most, only two amplifiers, so that a number of circuits may be employed in parallel to obtain several points during one measurement period. Data for the distribution curve of a Gaussian noise generator was presented to demonstrate the precision of measurement.

The circuit submitted for the estimation of variance consisted of an absolute-value circuit (or precision full-wave rectifier) followed by an integrator. It was shown that if the probability distribution of the process is known, then the integrator output can be related to the process variance by a constant "form factor" derived from the distribution characteristics.

The variance circuit preceded by an appropriate bandpass filter was suggested as a very useful program

*Done in collaboration with *J. L. Hammond*, also of Georgia Tech.

for the measurement of points on the power spectral-density curve. However, in addition to the form factor mentioned, it is also necessary to compute a "filter factor," which depends on the transmission characteristics of the filter. This factor can be conveniently determined by using the computer to find the integral of the squared impulse response.

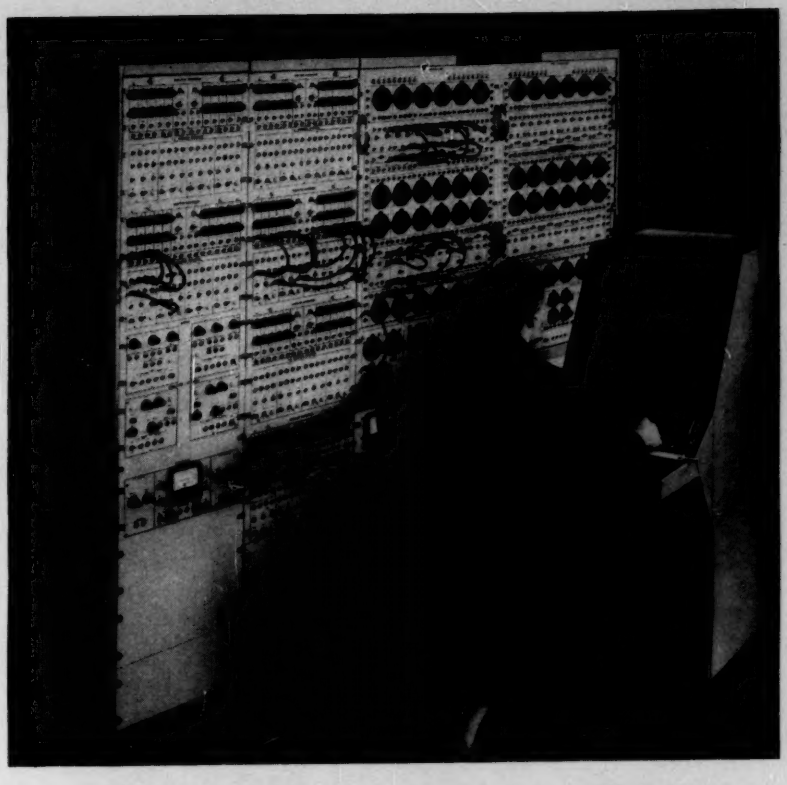
The paper brought out several reminders concerning the accuracy of sample measurements relative to true process statistics. In addition to possible errors due to departures from assumed conditions of ergodicity and stationarity in the process under study, very large errors may be introduced by failure to take sufficiently long time samples. For example, it was shown that in the estimation of the power density at 0.1 cps using a filter having a Q of 10, it requires some 11 hours of sample measurement to obtain 10% accuracy with 95% certainty.

Bob concluded his talk with a short description of the low-frequency Gaussian noise generator built at Georgia Tech, and a few comments concerning the applications of such a device.

EASTERN S/C MEETING OF 24 NOV ON PROCESS CONTROLLERS

Ye Ed's alma mammy, Leeds & Northrup, was host to the Eastern Simulation Council meeting on 24 November 1959, but not at the old Germantown Location I knew so well. The meeting was at their new plant and Research & Development Center in North Wales, Pennsylvania.

The first paper on the program was "Simulation of Industrial Process Controllers" by *R. L. Farrenkopf* and *F. A. Lapinski* (Brown Instruments Div., Minneapolis-Honeywell Reg. Co.). *Sidney Korn* (Sylvania Electronics Systems, Waltham 54, Mass.), then Secretary and now Chairman of the Eastern Simulation Council, was kind enough to furnish us with notes on this talk, but no further comment. As we were not there we will make no pretense of telling you what the speaker said. But as we consider the subject of interest we will pass on most of the notes just as we received them.



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Farrenkopf and Lapinski on Simulation of Process Controllers

Basic Block Diagrams of Controllers

A. 2-mode—proportional plus integral (reset) is shown in Fig. 1, where K = gain = 100/proportional band, T_1 = reset time-constant.

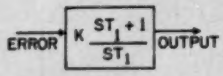


Fig. 1

B. 3-mode rate before reset—proportional plus integral and compensated derivative (rate), is shown in Fig. 2, where K = gain, T_1 = reset

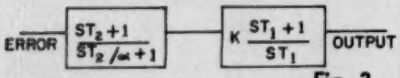
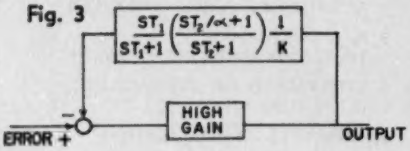


Fig. 2

time-constant, T_2 = rate time-constant, α = rate time constant ratio.

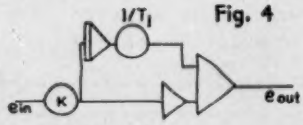
C. 3-mode reset before rate—proportional plus integral and compensated derivative, is shown in Fig. 3. For linear simulation this becomes the same as Fig. 2.

Fig. 3



Basic *linear* computer diagrams are shown in Figs. 4 (2 mode) and 5 (3 mode).

Fig. 4



These simple simulations are often inadequate. Use of the above simple simulations usually depends on the assumption that: (1) no element in the real controller saturates, (2) the controller amplifier has infinite gain and input impedance, (3) frequency characteristics are determined solely by the modes. However, most controllers are built in the way shown in Fig. 6, and often (due primarily to amplifier characteristics) the above assumptions are not justified.

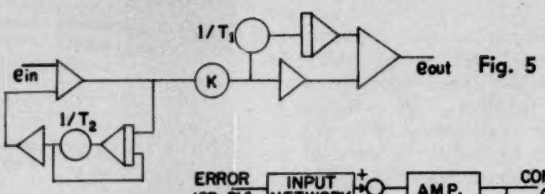


Fig. 5

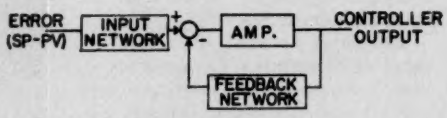


Fig. 6

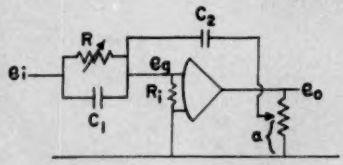
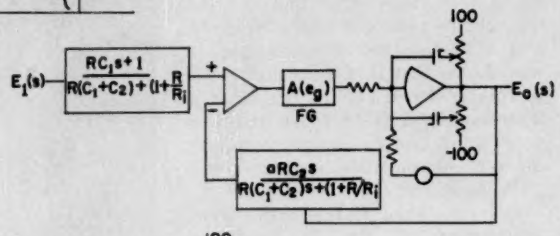
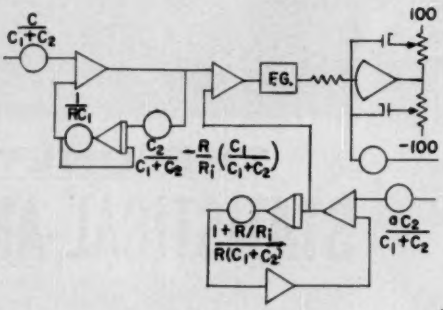


Fig. 7



A



B

Fig. 8

Example: Simulate the 2-mode electronic controller in Fig. 7. By summing currents at the grid and La-Place transforming, the result is:

$$E_z(s) = \frac{(RC_1 s + 1)\ E_i(s)}{R(C_1 + C_2)s + (1 + R/R_i)} + \frac{(a\,RC_2\,s)\ E_o\,(s)}{R\,(C_1+C_2)\,s + (1+R/R_i)}$$

This equation holds for all the controller states.

Assume the amplifier to have saturation limits and to be described by $e_o = A(e_z)e_z$. Then the simulation is as shown in Fig. 8 A and B.

As the amplifier gain approaches infinity this reduces to Fig. 9.

Electric three mode controllers can be handled similarly.

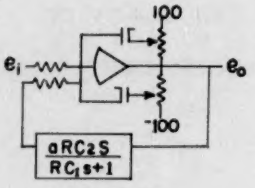


Fig. 9

Pneumatic controllers

A usual characteristic of pneumatic controllers is the isolation between their input and feedback networks. A typical 2-mode controller is illustrated in Fig. 10 and its simulation in Fig. 11.

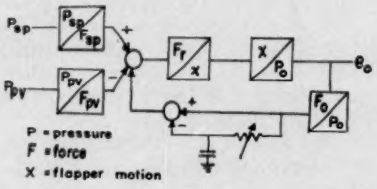


Fig. 10

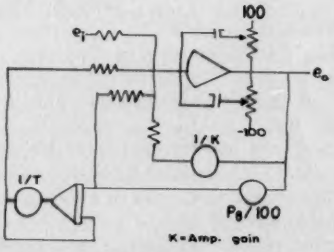
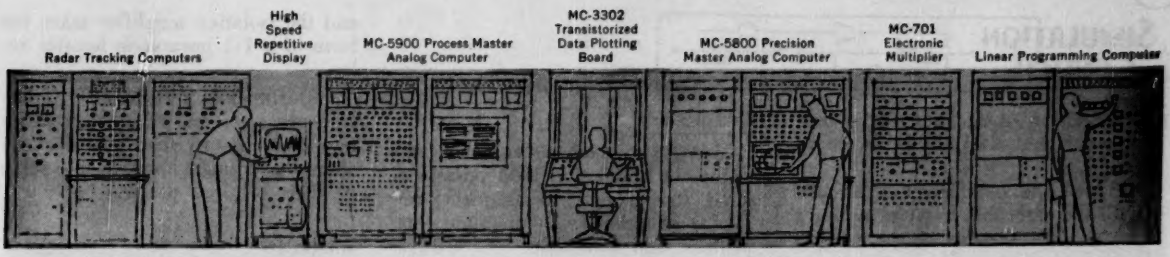


Fig. 11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SIMULATION COUNCIL

Simulation of a compensated proportional plus rate unit is shown in Fig. 12.

A cascade of these two circuits (with the rate unit first) provides a three-mode controller of the rate-before-reset variety.

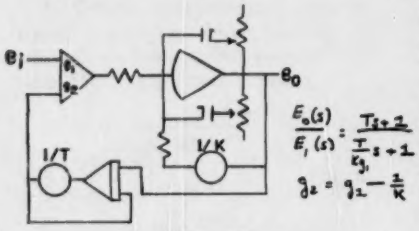


Fig. 12

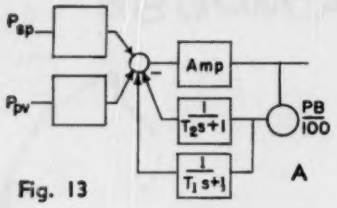
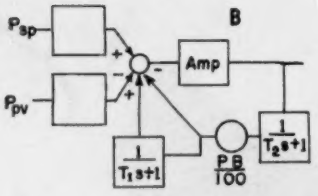


Fig. 13



Other three-mode configurations (Fig. 13) can be simulated by similar techniques.

Hausner on Simulation of Cascaded Process Lags

In contrast to the foregoing rather cryptic notes, there was another paper presented at that meeting which we think is of sufficient interest to warrant our presenting it in full. So here it is: *Idealized versus Realistic Simulation of Cascaded Process Lags,* by Morton J. Hausner (Fischer & Porter Co., Hatboro, Penna.)

Abstract

Certain pitfalls await the engineer entering the field of process control system simulation. One of these pitfalls is the tendency to idealize or oversimplify process characteristics. Basic differences between oversimplified and realistic simulations are defined and discussed with the help of examples.

Background

Many process control engineers entering the simulation field possess a good background in frequency-response techniques. By manipulating process and controller characteristics on Bode diagrams, the engineer has at his command a powerful tool for both synthesis and analysis, with relatively little mathematics involved. The process is usually treated as a series of lags (time constants) which can be graphically added to find the overall response of the process. The logarithms of the gains (magnitude ratios) of the lags are graphically added to form the logarithm of the product of the gains and the phase angles are graphically added to form the total phase angle. This is a powerful tool when used correctly. This tendency to treat some processes as a series of isolated lags might possibly carry over into simulation studies causing erroneous results. This is especially true when working on a process which is in the design stage where no field data can be obtained.

Definitions

To illustrate the basic differences between isolated (non-interacting) and non-isolated (interacting) process lags, several analogies will be used. Fig. 14 represents the electrical analogy of a two-time-constant process. Fig. A is called interacting because current flows between V_2 and V_o. In other words, the second time constant loads down the first one. Fig. B is called non-interacting because an isolation amplifier is placed between V_2 and R_2, preventing any current from flowing between the first and second time constants. Fig. 15 represents the pneumatic analogy of the same situation where pressures replace voltages, restrictions replace resistors, volumes replace capacitors, and the isolation amplifier takes the form of a 1:1 pneumatic booster relay.

Unfortunately a great many industrial processes consist of series of interacting lags so that frequency-response techniques begin to lose some of their original power.

Analysis

The mathematical differences between the two types covered above will now be covered using the familiar water tank analogy. Fig. 16 shows

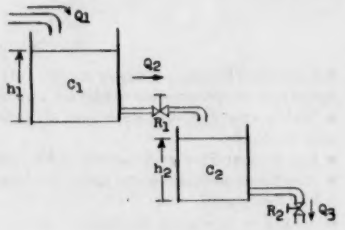


Fig. 16

a series of water tanks connected in non-interacting fashion. The second tank does not, in any way, affect the behavior of the head or flow out of the first tank. In other words, the second tank does not load the first one.

The process equations are:

$$C_1h_1S = Q_1 - Q_2 \qquad (1)$$

$$Q_2 = h_1/R_1 \qquad (2)$$

$$C_2h_2S = Q_2 - Q_3 \qquad (3)$$

$$Q_3 = h_2/R_2 \qquad (4)$$

By combining (1) and (2) to find h_1, and combining (3) and (4) to find h_2, we find that

$$\frac{h_2}{Q_1} = \frac{R_2}{(R_1C_1S+1)(R_2C_2S+1)}$$

In this example the transfer function indicates two non-interacting lags.

Fig. 14

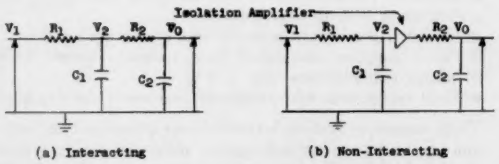


Fig. 15

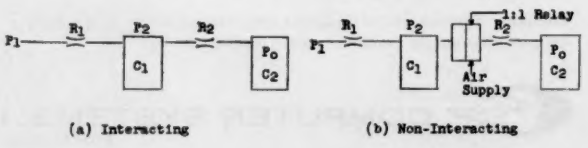


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Fig. 17 shows the same tanks tied together in interacting fashion. The level in the second tank affects the flow out of the first tank.

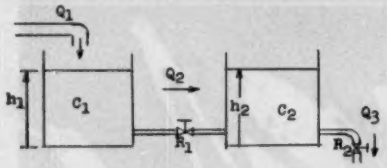

Fig. 17

The process equations are:

$$C_1h_1S = Q_1 - Q_2 \quad (1)$$

$$Q_2 = (h_1 - h_2)/R_1 \quad (2)$$

$$C_2h_2S = Q_2 - Q_3 \quad (3)$$

$$Q_3 = h_2/R_2 \quad (4)$$

By combining we find that

$$\frac{h_2}{Q_1} = \frac{R_2}{(R_2C_2S+1)(R_1C_1S+1)+R_2C_1S}$$

A comparison of transfer functions shows an additional term in the denominator which may be attributed to interaction. For use in frequency response, the transfer function of the interacting system may be factored to form an equivalent non-interacting process.

For example, suppose $R_1 = R_2 = 0.1$ min/ft^2 and $C_1 = C_2 = 5$ ft^2, so that $R_1C_1 = R_2C_2 = R_2C_1 = 0.5$ min. The transfer function is now:

$$\frac{h_2}{Q_1} = \frac{0.1}{(0.5S+1)(0.5S+1)+0.5S}$$

$$\frac{h_2}{Q_1} = \frac{0.1}{0.25S^2+1.5S+1} = \frac{0.1}{(1.31S+1)(0.191S+1)}$$

Note that the interacting process was changed from two equal lags to a non-interacting process consisting of a larger and a smaller lag.

In general, when a series of interacting lags is converted into an equivalent series of non-interacting lags the new values of time constants will be spread further apart in the frequency spectrum.

To illustrate this phenomenon, consider a process composed of three equal time constants where:

$R_1 = R_2 = R_3 = 2$ minutes/ft^2 and $C_1 = C_2 = C_3 = 1$ ft^2.

For the non-interacting case, the transfer function is:

$$1/(2S+1)(2S+1)(2S+1)$$

For the interacting case, the transfer function is:

$$1/8S^3+20S^2+12S+1$$

When this expression is factored the resulting transfer function is:

$$1/(10S+1)(1.33S+1)(0.60S+1)$$

The time constants are seen to be spread far apart. When the original time-constants are unequal to begin with, the equivalent non-interacting time constants will be spread further apart.

The interacting process is an "easier" one to control. The frequency at which the process reaches 150° phase shift is used to determine the permissible proportional controller gain. The interacting system reaches a higher frequency before shifting 150°. At the same time it has attenuated much more than the non-interacting process. The interacting process will tolerate much higher controller gain before instability occurs. This can be seen from the Bode plot.

As the number of time constants gets larger in an interacting system, frequency-response techniques become unwieldy and analog simulation becomes more justified.

Applications

As a more realistic example of an interacting process, we will study the case of the often used batch heat up of a jacketed vessel[1] shown in Fig. 18.

The vessel is assumed to contain a perfectly mixed batch with negligible heat loss through the insulation. The

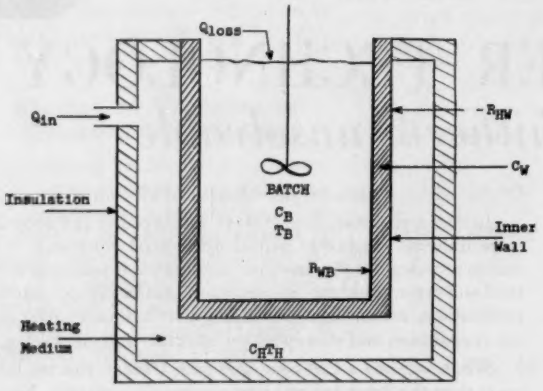

Fig. 18

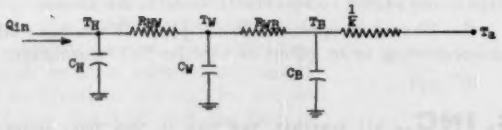

Fig. 19

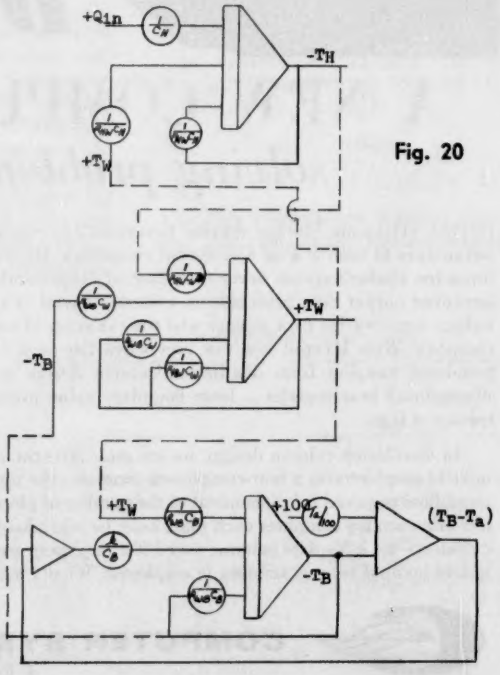

Fig. 20

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Time Delay Unit Simulates Fluid Transport

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A prominent feature of nuclear power plants and many chemical processes is the flow of fluids from one energy exchange point to another. In the case of reactors there is the flow of coolant from core to heat exchanger and back; in chemical processes, the movement of chemicals from one reaction chamber to another. When simulating such systems it becomes necessary to introduce rather long time delays corresponding to the time the fluid is in transport but otherwise unchanged.

The delays required are likely to fall in the range of a tenth of a second to ten seconds. Because fluid turbulence removes sudden changes in the temperature or chemical composition of fluids, the signal to be delayed usually consists of low frequency components – on the order of one cps or less.

The EASE 1152 transport delay shown below was developed to cope with these conditions.

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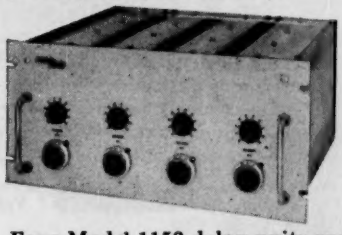

Four Model 1152 delay units are shown above mounted in 8¾" of rack space. In operation each delay unit must be supplemented by three operational amplifiers. Each unit has a 10-position switch (top) for selecting the integral number of seconds and a 10-turn dial (bottom) for selecting the fractional increment. Signal delay is continuously adjustable from about .010 secs to 10.000 secs. The shape and amplitude of the signal remain essentially unchanged. (Amplitude error is less than ±.01% at dc and ±0.3% at highest specified input frequency.) In this respect the unit is far more accurate than magnetic storage delays which are subject to considerable dc drift.

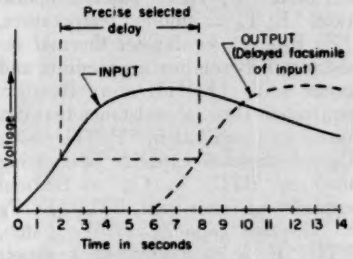

Figure 1. Graphic representation of a delayed signal.

The maximum usable delay depends upon input frequency. In order to operate with specified time accuracy, the delay (t) in seconds should be limited to

$$t = \frac{1.2}{f} \qquad (1)$$

where f is the frequency of the highest frequency component of interest. Thus, if the highest component is lcps, 1.2 seconds is the maximum delay. The slower signals commonly encountered may be delayed for several seconds as diagramed in Figure 1. Moreover, maximum delay time may be doubled, tripled or quadrupled by cascading delay units. The effect is to add delay times while preserving percentage accuracy.

Note that it makes no difference what time scale is used in the problem. For example, if solution time is doubled, maximum delay time also doubles because frequency in equation (1) is reduced to one-half.

Design Optimizes Accuracy, Reduces Need for Amplifiers

The basis of the time delay is a circuit which induces phase shift that varies linearly with input frequency. Thus, for example, if frequency doubles, phase shift doubles and time delay remains exactly the same.

In the circuit used, phase shifts up to 425° occur as a linear function of frequency. This range is approximately 40% larger than that which can be achieved using the Padé approximation. Figure 2 shows phase error of only 1.1% at 425°.

The total possible error in delay time is equal to the phase error plus a slight error introduced by the finite resolution of the delay control. Resolution error amounts to only 0.25% of value for delays in the range of 0.4 to 10 seconds.

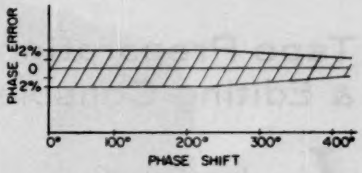

Figure 2. Phase error plotted against phase shift. 425° phase shift corresponds to maximum usable delay (t = 1.2/f).

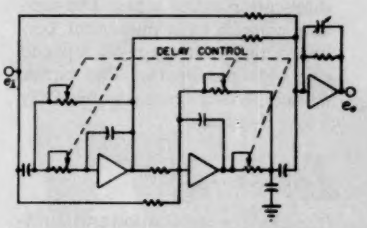

Figure 3. The delay circuit used. Note that only three operational amplifiers are required. This simple circuit possesses the complex transfer function required for accurate delays: 4th order in the numerator and 5th order in the denominator.

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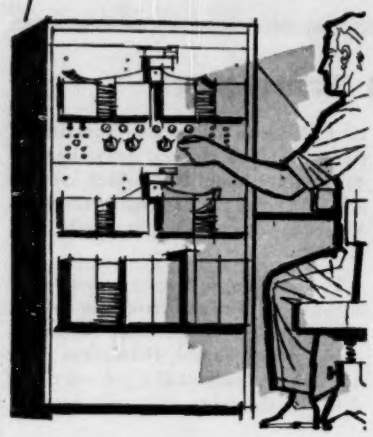

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equations will be derived working from point-to-point, starting at the heat input. An equivalent electrical network helps to visualize the problem (Fig. 19).

T_H = temperature of heating medium, °F; T_W = temperature of inner wall, °F; T_B = batch temperature, °F; T_A = ambient temperature, °F; R_{HW} = equivalent thermal resistance between heating medium and inner wall, °F/BTU/min; R_{WB} = equivalent thermal resistance between inner wall and batch, °F/BTU/min; C_H = thermal capacity of heating medium, BTU/°F; C_W = thermal capacity of inner wall, BTU/°F; C_B = thermal capacity of the batch, BTU/°F; k = conduction constant between batch and ambient, BTU/min-°F.

$$Q_{in} = T_H C_H S + (T_H - T_W)/R_{HW}$$

$$(T_H - T_W)/R_{HW} = T_W C_W S + (T_W - T_B)/R_{WB}$$

$$(T_W - T_B)/R_{WB} = T_B C_B S + (T_B - T_a)k$$

By taking the equations one at a time, converting them into convenient form and drawing the individual computer diagram the complete system simulation is accomplished. All the interactions are included in the simulation and any of the intermediate temperatures may be examined. The effects of vessel design changes are easily studied by changing the proper potentiometers. (Fig. 20).

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Another possibility for simulation that has been used is a passive network such as the circuit in Fig. 19. A current output is needed to form the analog of heat into the system. A fine example of this direct simulation technique is a distillation column study by Rijnsdorp and Maarleveld[2], where most of the process was simulated using passive elements, thus saving a tremendous amount of amplifiers.

Conclusions

A reiteration of the important points is in order. The transition from frequency-response techniques to analog simulation requires a change in thinking with regards to processes in the design stage. A close look at the process by means of equations or equivalent circuits will help take into account the interactions essential to a realistic simulation.

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1. Franks, Pink and Worley: Process-Control Problems Yield to the Analog Computer. *Control Engineering.* June, 1957.
2. Rijnsdrop & Maarleveld: Use of Electrical Analogues in the Study of the Dynamic Behavior and Control of Distillation Columns. Symposium on Instrumentation and Computation in Process Development and Plant Design, Institution of Chemical Engineers, 16 Belgrave Square, London S. W. I.

* * *

In the Leeds & Northrup Eastern Simulation Council meeting there was a discussion of method of steepest ascent and a reference to an article by Box and Wilson. *Hans Meissinger* has done a lot of work in this area:

1. Simulation Council Newletter, *Instruments and Automation,* pp 1546-7 Vol. 31, September 1958.
2. F. L. Gephart, "Linear Algebraic Systems and the REAC," Math. Tables and other aids for Comp., 6, pp 190-203, (1952).
3. H. F. Meissinger and L. Levine, "An Automatic Computer Circuit for Solving Polynomials and Finding Root Loci." *IRE Convention Record,* 1957. Part 4, pp 164-172.
4. I. B. Pyne, "Linear Programming on an Analog Computer," *AIEE Trans.* 1956, Part I, pp 139-143.
5. O. L. Davies, *Design and Analysis of Industrial Experiments, Chapter* 11, Hafner, New York, 1956.

Reference 3 in particular is believed to represent some original work of unusual interest.

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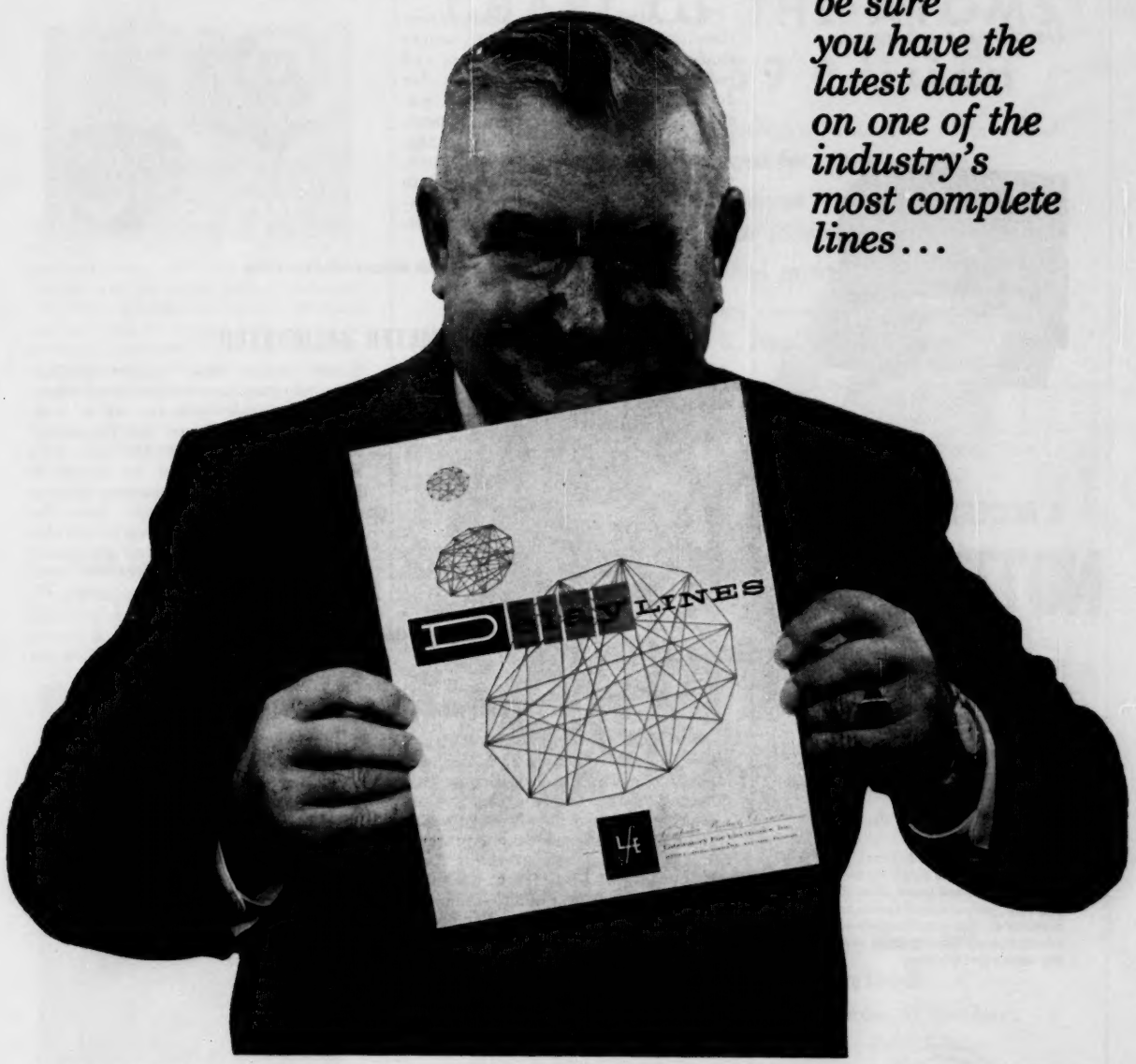

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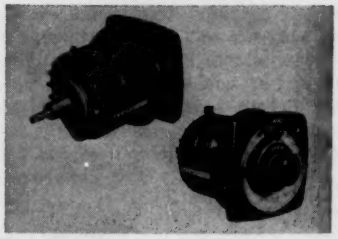

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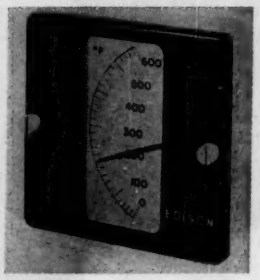

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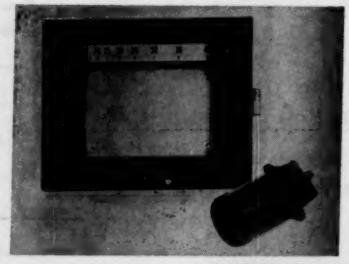

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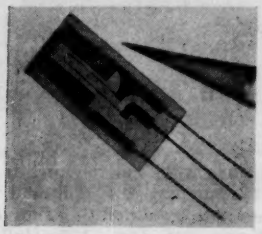

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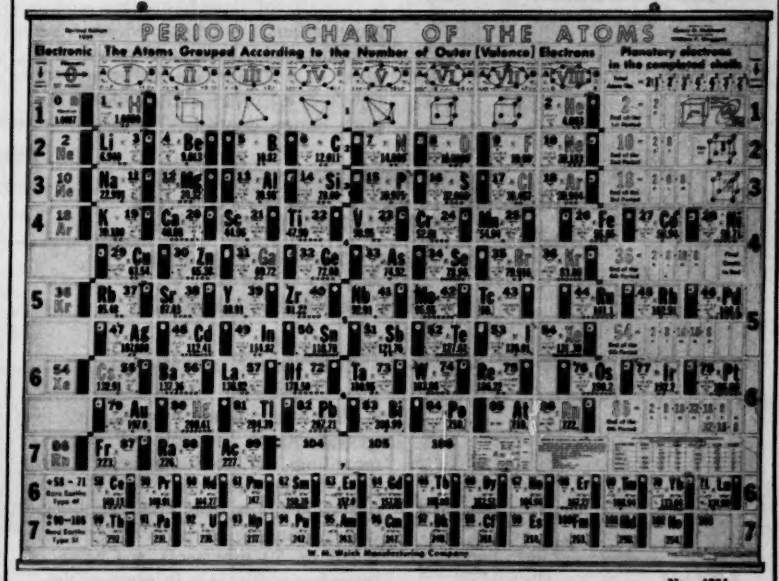

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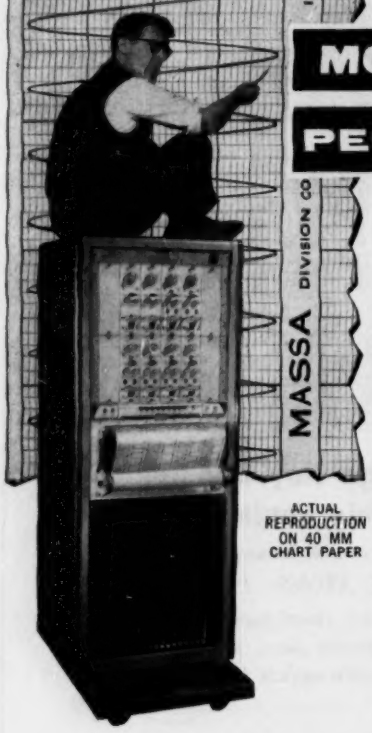

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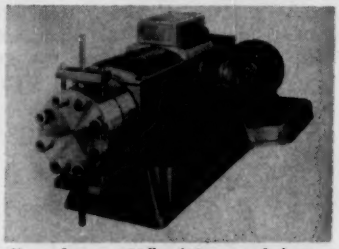
FEEDWATER PUMP

New Model CPS-4 Pulsafeeder Positive Displacement Pumps for direct injection of feedwater chemicals into

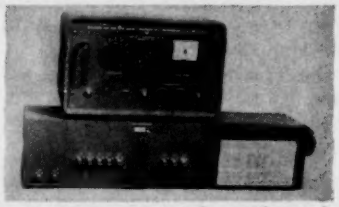


boilers has a ½" piston and is capable of pumping 9.4 gph and 3200 psig.—*Lapp Insulator Co., Inc., Process Equipment Div., 108 Hall St., Le Roy, N. Y.*

CIRCLE 186 ON READER-SERVICE CARD

PRECISION PHASE DETECTOR

New Type 205B2 Precision Phase Detector with frequency range from 200 Mc to 1000 Mc and an accuracy of ±0.050 or +1% is based on a comparison principle. Essentially it

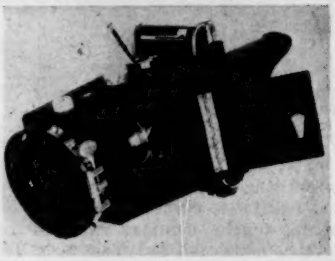


consists of a coaxial continuously-variable delay line and a sensitive phase detector. Specifications: Resolution—less than 0.01 μμsec; time delay—adjustable from 0 to 1.4 μμsec; total delay—37.5 μμsec in E_1 channel and 7.5 μμsec in E_2 channel.—*Ad-Yu Electronics Lab., Inc., 249-259 Terhune Ave., Passiac, N. J.*

CIRCLE 187 ON READER-SERVICE CARD

OSCILLOSCOPE CAMERA

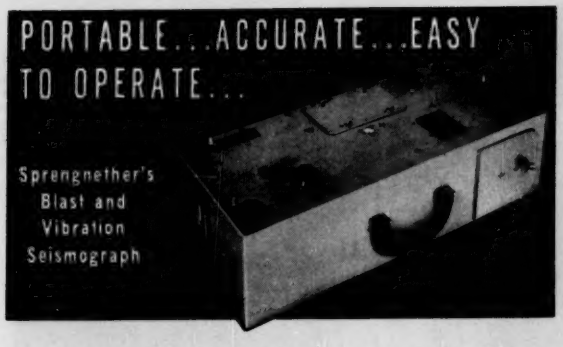
New Oscilloscope Camera, Model 196A, uses Polaroid Land film and has an object-to-image-size ratio of 1:0.9 to show a full 10 cm graticule



width. Lens adjustments may be made without removing the camera from the scope. While making an exposure, the operator can observe the pattern with both eyes.—*Hewlett-Packard Co., 275 Page Mill Rd., Palo Alto, Calif.*

CIRCLE 188 ON READER-SERVICE CARD

PORTABLE...ACCURATE...EASY TO OPERATE...



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Typical Applications:

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- Rocket Engine Testing
- Measuring Vibration Effects to Plant and Equipment from Operating Heavy Machinery.
- Determine Vibration Response of Members During Construction and After Completion of Building.

Portability: (38 lbs.—25 x 10 x 8 in.) Unit is self contained and free from external power source.

Extremely Accurate: To guard against error, each instrument is tested and calibration data furnished. Frequency response, 3 to 200 cycles per second. Timing lines are across record at intervals of 0.02 seconds with accuracy of 0.1%.

Easy To Operate: All controls are easily accessible. Instrument can be set up, leveled and made ready to operate within minutes.

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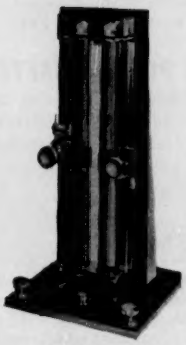
PRECISION

MANOMETER



The versatile micromanometer which can be operated at high working pressures. A simple U-tube with vernier readers makes it possible to offer this exclusive combination of features:

- 150 PSIG maximum working pressure.
- ± 0.001 inch sensitivity.
- Water or mercury can be used.
- Forward or reverse use without changing connections.
- Range —9 to +11 inches.

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CIRCLE 80 ON READER-SERVICE CARD

YOUR POTENTIOMETRIC INSTRUMENTS

NO matter how perfect otherwise, the human organism isn't much good without a dependable heart. The same is true of your automatic temperature and pH control instruments.

The "heart" of most such instruments for the past quarter century has been the Eplab Standard Cell. It is a "yardstick" for translation of voltage to temperature or pH. The first American commercial cell of its type, constantly improved by research, it is "as standard as sterling".

Get ACCURATE temperature or pH control with potentiometers and make sure the standard cells are EPLAB.

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FOR POTENTIOMETRIC INSTRUMENTS

"As Standard as Sterling"

CIRCLE 81 ON READER-SERVICE CARD

STILL THE MOST ACCURATE SIZE 11 RESOLVER

in a new, shorter mechanical construction

Without sacrifice of its unique 0.03% functional error and at significant reduction in cost to purchasers, the DIEHL B 11R 9-1 Resolver is now available in an over-all length of only 2.25".

Complete mechanical redesign of the unit has provided this length and cost reduction together with optional provision for a rear shaft extension. Terminal connections are available either with leads (as illustrated) or soldering lugs.

In addition to a standard line of low and high impedance (compensated or uncompensated) windings the unit can be obtained with special windings for operation at frequencies as high as 2 megacycles.

A still shorter unit, 1.750" in length, is available with the same 0.03% functional error but with comparatively lower impedances.

We invite engineers seeking to design more accurate computers to ask us for full details about these exceptionally precise new resolvers.

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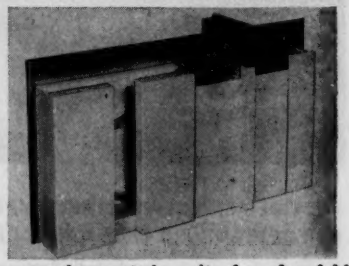
CIRCLE 82 ON READER-SERVICE CARD

PAPER TAPE PERFORATOR

New self-contained Tape Perforator, punching paper tapes at rates to 60 characters/sec, accepts tape of varying widths up to 8 channels. Available in two models: Model 420PF,

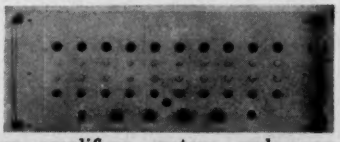


a panel-mounted unit for fan-fold tape handling, and Model 420PR, using reels. Non-synchronous drive can be operated at any speed if the minimum time interval between cycles is not less than 16-⅔ msec. The capstan is driven by the bi-directional tape transport for driving tape backward any distance to correct or modify tape already punched.—*Tally Register Corp.*, 5300—14*th Ave. N. W., Seattle 7, Wash.*

CIRCLE 189 ON READER-SERVICE CARD

CHANNEL SEPARATOR

New SCS-1B Subcommutator Channel Separator decommutates ten 100% duty-cycle channels and the outputs are available to drive oscillographs,



pen amplifiers, meters, and servo channels. Designed for use with an Arnoux telemetering decommutation system, it accepts subcommutated wave trains at any rate from 30 to 120 pulses/sec at approximately 0 to 40 v for 0 to 100% information.—*Arnoux Corp.*, 11924 *W. Washington Blvd., Los Angeles* 66, *Calif.*

CIRCLE 190 ON READER-SERVICE CARD

MULTITURN POTENTIOMETER

New Model 0610M, a ½"-dia ten-turn Potentiometer which meets or exceeds environmental requirements

of Mil-E-5272B and NAS 710 is available in all conventional resistance values as well as in non-linear versions. Features include low-leakage, stop torque limits of 25 in-oz, and linearity to 0.05%.—*Analogue Controls, Inc.*, 200 *Frank Rd., Hicksville, N. Y.*

CIRCLE 191 ON READER-SERVICE CARD

SAFETY RELIEF VALVE

New Safety Relief Valve the 500 Series features a patented seat which provides a constant seal of the seat to the plunger with the sealing pressure increasing as the inlet pressure builds up, and completely-sealed top-works and spring components, which makes it completely resistant to all corrosive liquids and gases except hydrofluoric acid and hot concentrated caustics. Three models constructed of pyrex glass and Teflon are for pressure, vacuum relief, or vacuum and pressure.—*Chem Flow Corp.*, 117 *Dell Glen Ave., Lodi, N. J.*

CIRCLE 192 ON READER-SERVICE CARD

ULTRASONIC FLAW ALARM

Three new flaw alarms (Models A, B, & C) for electronic monitoring have a single gate time which is adjustable for position, length, and duration. All three flaw alarms have two outputs in common: (1) a red defect-indicator light mounted on the front panel of the instrument, (2) a 5 vdc (no load) signal fed through a coaxial connector on the back panel which triggers audible alarms or markers, or starts corrective action. Alarms are accessories to the Sonary pulse-echo flaw detectors.—*Branson Instruments, Inc.*, 40 *Brown House Rd., Stamford, Conn.*

CIRCLE 193 ON READER-SERVICE CARD

control vacuum, pressure and flow AUTOMATICALLY with ONE ELEMENT!

CARTESIAN MANOSTAT #10*

Put the Cartesian Manostat #10 in your system—set it and forget it! Self-contained unit operates automatically, economically, accurately!

Interchangeable balanced orifice (choice of 3/16", 3/4", or .070") preserves sensitivity at high capacity, permits direct or reverse action in same instrument.

Cartesian Manostat #10 complete and ready for use, with mercury. $350.00

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*Patent Applied For

CIRCLE 83 ON READER-SERVICE CARD

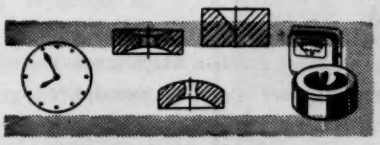
PRECISION

defined by the dictionary

. . . . "the quality or state of being precise; accuracy; mechanical exactness."

defined by an instrument maker . . .

Swiss American



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- exact tolerances
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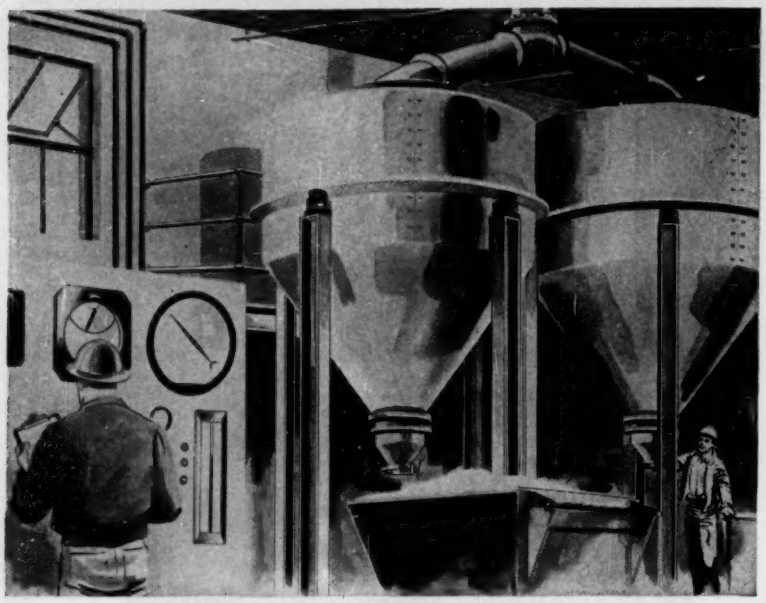
EMERY ENGINEERED WEIGHING SYSTEM

Provides Maximum Accuracy for Pulverized Vitamin C Installation



Explosion-Proof Equipment Provides Control For Hopper-Filling Mechanism

A pharmaceutical manufacturer wanted to weigh powdered ascorbic acid as part of its process in making Vitamin C tablets. The powder is gathered in hoppers which weigh 3500 pounds and handle a maximum net load of 8750 pounds.

The conditions demanded that the equipment be explosion-proof and that the weighing signal be used to actuate automatically a diverting gate in the filling system which would switch the in-flow from one hopper to another.

An Emery Engineered Weighing System, based on the use of 4 Model EC-30 load cells and a hydraulic totalizer and using a 16" Emery Precision Indicator together with a Foxboro controller, handled the hopper-weighing job with an accuracy of ¼% of full range. Customer satisfaction is guaranteed.

If you have a tank, bin or hopper weighing problem which involves a control function, write today. Our literature is graphic, descriptive and easy to use in figuring a system for your installation. The A. H. Emery Company, Pine Street, New Canaan, Conn.

EMERY Engineered weighing sy

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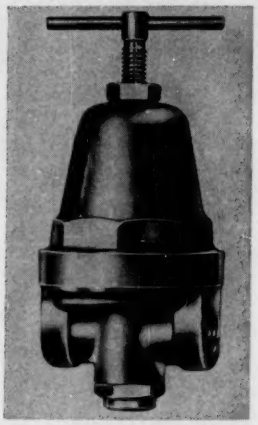
NEW INSTRUMENTS

PRESSURE REGULATORS

New Type A-360 and A-361 Series Pressure Reducing and Regulating valves feature a specially balanced internal-piston design whereby outlet pressures are not affected by wide

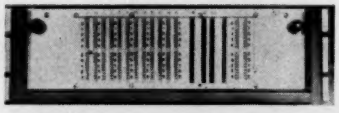


variations in inlet pressures or variable rates of flow. Type A-360 Series has female inlets and outlets. Type A-361 Series are for three or four way use. Both series are available in ¼", ⅜" and ½" sizes. Bulletin No. 1-17 gives details.—*Cash-Acme, Box* 191, *Decatur, Ill.*

CIRCLE 194 ON READER-SERVICE CARD

ANALOG COMPUTER CONTROL SYSTEM

New line of solid-state, electronic PowrMag Controls, containing no tubes, slide wires, or transistors, adaptable to simple single controller installations or to large multi-plant systems with direct tie-in to data processing or digital computing equipment, consists of four basic elements:



(1) input transducers which convert input variables such as pressure, flows, temperatures, and levels into 1-9vdc electrical signals; (2) analog control computers, composed of a tamperproof plug-in patchboard and operational magnetic amplifiers; (3) remote control stations; and (4) final control units such as electro-pneumatic and electrohydraulic valves and power positioners in the range of 1-5 ma or 1-9 ma. Patchboard is illustrated. Bulletin MSP-163 gives details.—*Controls Div., Hagan Chemicals & Controls, Inc., Hagan Bldg., Pittsburgh* 30, *Pa.*

CIRCLE 195 ON READER-SERVICE CARD

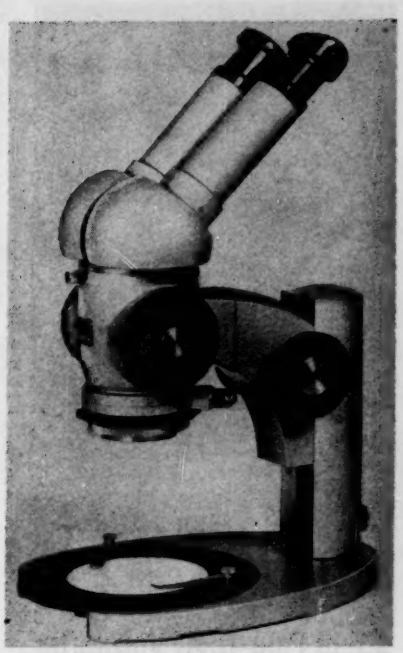
New CARL ZEISS STEREO-MICROSCOPE II

MADE IN WEST GERMANY

This sturdy, compact instrument produces an image of outstanding plasticity—erect, unreversed, and uniformly sharp over the entire field of view. It is easy on the eyes, even under prolonged observation.

Offers novel, rapid change of magnification from 2.5x to 100x, with wide-angle oculars.

Affords a large working distance—3-1/8 inches—with diameter of object field up to 50mm. Beyond 100x magnification, a 2x supplementary objective is available, having a working distance of 1-1/8".



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VAN-AIR DRYERS require NO regeneration, heat, power, injection or volume loss — operate automatically — deliver air dry, clean, sterile, non-toxic. Built in sizes to treat any volume of compressor output — large or small — NO LIMIT.

PLANT ENGINEERS — Look into the DOLLAR economy and PENNY cost of VAN-conditioned compressed air. Ask for 16-page brochure with charts.

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Only VALCOR makes solenoid valves of

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Now, from the company that pioneered the use of Nylon and PVC in solenoid valves for corrosive service, comes a solenoid valve with a molded body and diaphragm of Teflon that is chemically inert and corrosion-resistant to virtually any corrosive medium you are now using.

Long life . . . outlasts and outperforms steel. Available in a variety of sizes and pressure ratings.

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VALCOR SOLENOID VALVES

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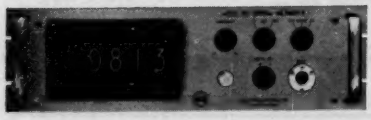
A Full Four-Digit Voltmeter at a Pointer Meter Price!



FOR THE FIRST TIME you can have the accuracy, speed and reliability of an NLS digital voltmeter with full four-digit resolution . . . for the price of a quality pointer meter. That's the dramatic story of the new NLS V64! Only NLS high-volume production techniques make it possible. Use low-cost, versatile V64 for a wide range of measuring jobs. See the V64 in action . . . contact NLS today!

BRIEF SPECIFICATIONS: Accuracy ±(.02% of reading plus 1 digit) . . full 4-digit resolution . . . measures DC voltages from one millivolt to 500 volts in steps of ±9.999/99.99/500.0 . . . one package design (5¼" high, 15¼" deep for 19" rack) . . . plug-in accessories permit measuring AC or low-level DC voltages . . . available from stock for immediate delivery.

NLS *Originator of the Digital Voltmeter*

non-linear systems inc.

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NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

CIRCLE 89 ON READER-SERVICE CARD

RECTILINEAR TRANSDUCERS

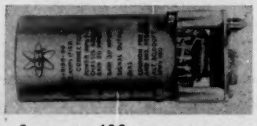
New Type KB Rectilinear Transducers are a-c electromechanical bridge-type units designed on the variable permeance principle to sense linear position for measurement and

control use. Five models, ranging from approximately 2" to 9½" length are built to withstand rapid environmental changes. Operation is recommended at 24 v rms maximum, with a carrier frequency of 3000 cps. Nonlinearity is 0.5% maximum or less in the rated range of 0.25" to 4". Bulletin KB-1 gives details.—*Crescent Engineering and Research Co., 5442-C North Peck Rd., El Monte, Calif.*

CIRCLE 196 ON READER-SERVICE CARD

MIN MAGNETIC AMPLIFIER

New miniaturized self-contained d-c Magnetic Amplifier, Model 92-0180-00, is for analog computations. Op-

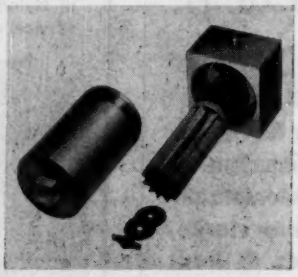


erates from a 400-cps power source. A high degree of linearity and stability is achieved through the use of multiple feedback loops.—*Communications Accessories Co., Lee's Summit, Mo.*

CIRCLE 197 ON READER-SERVICE CARD

HYDRAULIC FLUID FILTER

New type of Hydraulic Fluid Filter, featuring a reinforced sintered bronze 40-micron reusable filter element has a filter area of 35 sq in in the ⅜" size, assuring long, trouble-free service. Accumulation of foreign matter



causing a pressure drop of as much as 400 psi across the element will not cause the element to disintegrate. Also available is a similar assembly for ¾" pipe connections, utilizing two filter elements in parallel. The filters are for use with petroleum, ester, or glycol-based hydraulic fluids, silicones, water, and air.—*GPE Controls, Inc., 240 E. Ontario St., Chicago 11, Ill.*

CIRCLE 198 ON READER-SERVICE CARD

MERCOID CONTROLS

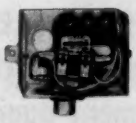
NEW CATALOG AVAILABLE

Write for your copy

Controls for—

- *PRESSURE*
- *TEMPERATURE*
- *LIQUID LEVEL*
- *MERCURY SWITCHES*
- *TRANSFORMER-RELAYS*

CHECK THESE NEW PRODUCTS BY MERCOID



TYPE AP-153

New SP-DT low pressure (instrument air) control. Small in size, light in weight. Provides any of following operations: SP cut-in high; SP cut-in low; or SP-DT operation. Two operating ranges 1 to 20 and 1 to 30 psig. External adjustments, visible dial and visible circuit position. See catalog No. 860

TYPE PG

New low pressure diaphragm control for gases or air. Can be used three ways; for pressure, negative (vac.) pressure or differential pressure. External adjustments, visible dial and visible on-off circuit position. Two operating ranges, 1.0" to 30.0" and 1/2 to 5 psig. See catalog No. 860

ASK FOR CATALOG NO. 860

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FLUID LEVEL • FLOW
available for
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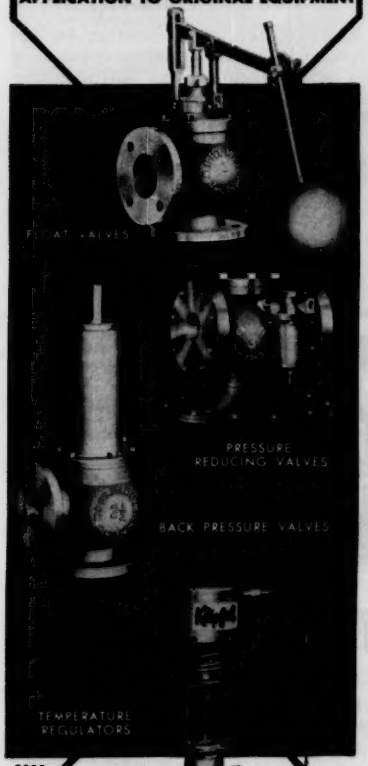
CHEMICALS
VISCOUS or ABRASIVE SLUDGES
EXPLOSIVE FLUIDS or VAPORS
APPLICATION TO ORIGINAL EQUIPMENT



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CIRCLE 91 ON READER-SERVICE CARD

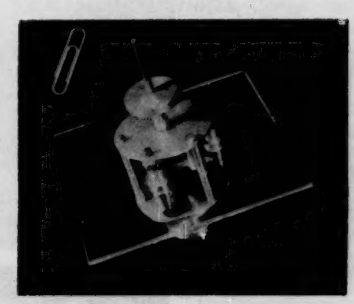
VACUUM GAGE

New battery-operated thermocouple Gage, for pressures from 2 mm Hg to one micron, primarily for monitoring the inter-shell pressure on liquid gas transport equipment, incorporates a Model 731 controller and a Model 521 replaceable sensing head. The Model 521 measures vacuum in terms of the amount of heat that the residual gas will conduct away from a hot wire. The Model 731 controller supplies the heater current to and interprets the output from the sensing head.—*NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass.*

CIRCLE 199 ON READER-SERVICE CARD

ROTARY SHAFT

New Hermetic Rotary Shaft Seal for vacuum or high-pressure service uses rotary motion of input shaft to move slotted arms of torsional shaft,



causing oscillating motion of torsion shaft. Uses torsion tubes of neoprene or other synthetic non-porous material or metal seals for extreme temperatures or pressures. Efficiency of power transmission is better than 95%. Operation up to 10,000 rpm is possible.—*Co-Engineering Company, Mountain Lakes, N. J.*

CIRCLE 200 ON READER-SERVICE CARD

PUNCHED-PAPER READER

New Model 3500 Dykor Photoelectric Reader is a completely solid-state unit which stops before the next char-

acter at reading speeds of 1000 characters/sec. All standard 5-, 6-, 7-, or 8-level tapes plus sprocket can be handled interchangeably.—*Digitronics Corp., Dykor Tape Reader Div., Albertson, L. I., N. Y.*

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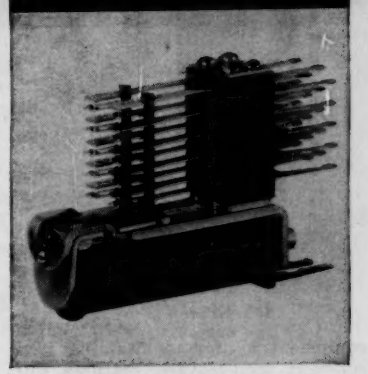
Stromberg-Carlson
RELAYS



...to meet your electromechanical switching needs

These are the very same twin-contact relays proven outstandingly successful through many years of precise, exacting operation in the telephone industry.

The following regular types are representative of our complete line:

Type A: a general-purpose relay with up to 20 Form "A" spring combinations.

Type B: a gang-type relay with up to 60 Form "A" spring combinations.

Type BB: accommodates up to 100 Form "A" spring combinations.

Type C: two relays on the same frame. A must where space is at a premium.

Type E: same characteristics as the Type A, plus universal mounting arrangement. Interchangeable with many other makes.

Types A, B and E are available in high-voltage models (insulation withstands 1500 volts A.C.) for test equipment and other high-voltage applications.

Details and specifications are in our complete relay catalog, available on request. Write to Telecommunication Industrial Sales.

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS
113 Carlson Road • Rochester 3, N. Y.

CIRCLE 92 ON READER-SERVICE CARD

LINEAR TEMP PROGRAMMER

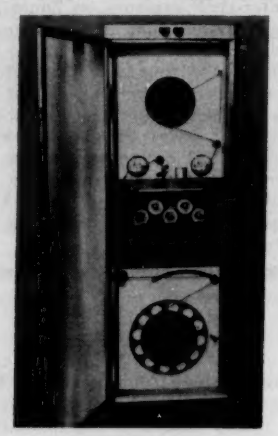
New portable, laboratory-type Linear Temperature Programmer, Model 40, designed for linearly increasing the temperature of heating

equipment or for maintaining it at constant temperature, features thirteen linear heating rates of from 0.8 to 44.3°C over the temperature range of 0 to 500°C. The unit is adaptable to other temperature ranges up to 1600°C. Bulletin contains details.—*F & M Scientific Corp.*, 1202 *Arnold Ave., New Castle County Air Base, New Castle, Del.*

CIRCLE 202 ON READER-SERVICE CARD

SOLVENT FILM CLEANER

New Unicorn Film Cleaner for automatic cleaning of motion picture films (negative and positive) and



magnetic recording tape operates at high speed, adjustable from 0-300 ft/min. Four models, completely self-contained and requiring no vacuum pumps or outside sources of air, are available. Model A-5100 is a combination for 16 or 35 mm; Model A-5116 cleans 16-mm film only, and Model A5135 cleans 35-mm only.—*Computer-Measurements Co.*, 12970 *Bradley Ave., Sylmar, Calif.*

CIRCLE 203 ON READER-SERVICE CARD

DIGITAL CLOCK

New 24-hour Digital Clock Type DY-2508A produces several staircase and decimal outputs simultaneously,

or a binary-coded decimal output. A special memory circuit holds the time display up to 0.9 sec for completion of the external recording or processing function.—*Dymec, Div. of Hewlett-Packard Co.*, 395 *Page Mill Rd., Palo Alto, Calif.*

CIRCLE 204 ON READER-SERVICE CARD

COMBUSTION INDICATORS

New Hazegage Combustion Indicators serve as smoke indicators as well as a dependable way to maintain maximum combustion efficiency. Every change in fuel or air adjustment or malfunctioning of furnace, burners, or controls is indicated immediately by red or green lights, making CO_2-sampling unnecessary. Applicable for new or existing boilers. —*Photomation, Inc.*, 96 *South Washington Ave., Bergenfield, N. J.*

CIRCLE 205 ON READER-SERVICE CARD

READ any surface temperature with Alnor® PYROCON

Equipment...material...metallic or non-metallic...flat, curved... revolving or stationary—you can read every surface temperature accurately in less than 3 seconds!

Compact, complete in precision design, this rugged instrument assures highest standards of speed, accuracy and dependability.

Alnor Portable Pyrocons come in scale ranges to 2000° F., with thermocouples for every application. You'll find full details on the Pyrocon exactly suited to your operations in Bulletin 4257. Send for your copy now. Write: Illinois Testing Laboratories, Inc., Room 518, 420 N. LaSalle St., Chicago 10, Ill.

Alnor PRECISION INSTRUMENTS FOR EVERY INDUSTRY

CIRCLE 93 ON READER-SERVICE CARD

GREEN PRINTED CIRCUIT DRILL

A Pneumatic Attachment on The Green Model D2 Pantograph Engraver rapidly drills holes in printed circuits by tracing templates.

- Drill as many as 100 holes per minute, Foot switch actuates air powered operation.
- Drill speeds and feeds have independent adjustments. Feed regulated by air pressure.
- Spindle speeds up to 26,000 rpm. Permits use of carbide drills when required.
- D2-201 air attachment includes spindle air cylinder, regulating valve and pressure gauge, foot switch, filter and oiler, ready to operate when connected to compressor.

The Model D2 Heavy Duty Pantograph Engraver features ratios of 2 to 1 to infinity. Unobstructed on three sides to handle large work. Micrometer adjustment for depth of cut. Vertical range 10" adjusting copy table automatically with pantograph.

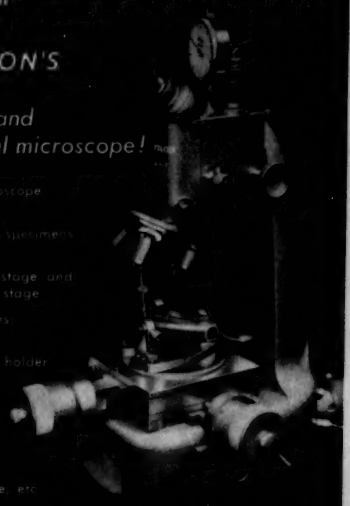
GREEN INSTRUMENT CO., INC.
384 Putnam Ave. • Cambridge 39, Mass.

FOR FULL DETAILS WRITE WIRE OR CALL

CIRCLE 94 ON READER-SERVICE CARD

MEASURE IN 3 DIMENSIONS TO 0.0001"

with UNITRON'S Combination Toolmakers and Metallurgical microscope!



- Direct reading from microscope screws and dial indicator
- Examines polished metal specimens at 30X, 100X, 400X, etc.
- Ball bearing rectangular stage and calibrated circular rotary stage
- Three separate illuminators: substage, surface, vertical
- Inclinable work and tool holder
- Accessories include viewing screen for 2-contour projection and optical comparison, eyepiece scales for measuring screw threads, diameters, metal grain size, etc.

Even the smallest shop can rapidly pay for this versatile instrument in time and materials saved. UNITRON Model TM, with all its features, costs about the same as the lowest priced, simple shop microscope. $1050 fob Boston only.

Write for Bulletin TM 22-Z

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
204-6 Mile Street • Boston 9, Mass.

CIRCLE 95 ON READER-SERVICE CARD

Your NEW SOURCE for f.h.p. motors

Precision diecast construction.
10 models, 1/35 - 1/10 h.p.
4½ x 3 1/16 x 3⅜" high.
3600 to 10,000 r.p.m.
Universal, shunt or series motors.
12v. to 220v. input.
Gear reduction and Speed Governor available.
Prompt Delivery
Liberal O.E.M. discounts.

Write for Prices and Specifications

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Large Enough to Serve You
Small Enough to Want to.

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Chicago 18, Ill.
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CIRCLE 97 ON READER-SERVICE CARD

---

3 new instruments for process control

MV-1 POTENTIOMETER

For testing, calibrating or servicing newest process controllers and amplifiers which convert millivolt input signals into proportional currents for control or telemetering. Combines all functions of precision potentiometer, millivolt source and milliammeter. 1/10 of 1% accuracy. 5⅛" x 8" x 5⅝". 5½ lbs.

THE AUTOCOMP 1

For instrument checking and thermocouple measuring. Gives automatic cold junction compensation to devices used for measuring or controlling with thermocouples. Exclusive circuit employs thermistor network to match non-linear characteristics of thermocouples with output characteristics of bridge. 5⅛" x 8" x 5⅝". 6 lbs.

RU-1 "RUN UP" SOURCE

Combination millivolt and milliampere "run up" source for instrument calibration. Checks newest process controllers and amplifiers. Current source furnished by two self-contained 90V batteries made to give stable, uniform outputs with cold cathode type voltage regulator tube. Self-contained. 5⅛" x 8" x 5⅝". 10 lbs.

TECHNIQUE ASSOCIATES

A Division of Duncan Electric Co., Inc.
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CIRCLE 96 ON READER-SERVICE CARD

Single-Point pH Recorder (Strip Chart Assemblies also available)

CAMBRIDGE pH INDICATORS and RECORDERS

Labor saving—profit producing!

In addition to portable pH meters, Cambridge makes line-operated Direct Reading pH Indicators and Recorders for permanent installation. They are accurate, stable and assure continuous and trouble-free performance. Either the Recorder, Indicator or both, may be located at any reasonable distance from one or several sampling points. The Glass Electrodes are placed in vapor-tight housings of clog-free sampling chambers.

Send for Bulletin

CAMBRIDGE pH EQUIPMENT

CAMBRIDGE INSTRUMENT CO., INC.
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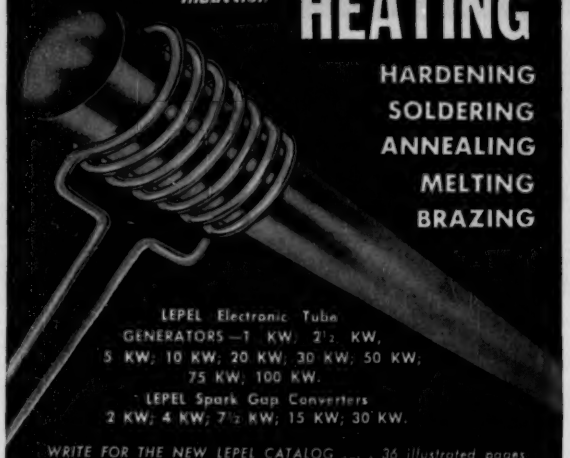
PIONEER MANUFACTURERS OF PRECISION INSTRUMENTS

CIRCLE 98 ON READER-SERVICE CARD

Lepel

HIGH FREQUENCY *Induction* HEATING

HARDENING
SOLDERING
ANNEALING
MELTING
BRAZING



LEPEL Electronic Tube
GENERATORS—1 KW; 2½ KW;
5 KW; 10 KW; 20 KW; 30 KW; 50 KW;
75 KW; 100 KW.
LEPEL Spark Gap Converters
2 KW; 4 KW; 7½ KW; 15 KW; 30 KW.

WRITE FOR THE NEW LEPEL CATALOG . . . . 36 illustrated pages packed with valuable information.

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CIRCLE 99 ON READER-SERVICE CARD

INSIDE THIS FOLDER you'll find hundreds of listings of geared and non-geared electric motors — complete with prices and all available for immediate delivery. HP from 1/2000 — Speeds from .65 RPM. Also contained in easy to find form are pages on Heller Controls and Lab Mixers, HGB Controls — Selenium and Silicon Rectifiers — Ther Rectifiers — all completely described and priced for off the shelf delivery. For your FREE COPY just off the press write today. **B & B Electric Motor Company, 206 Lafayette St., New York, N. Y.**

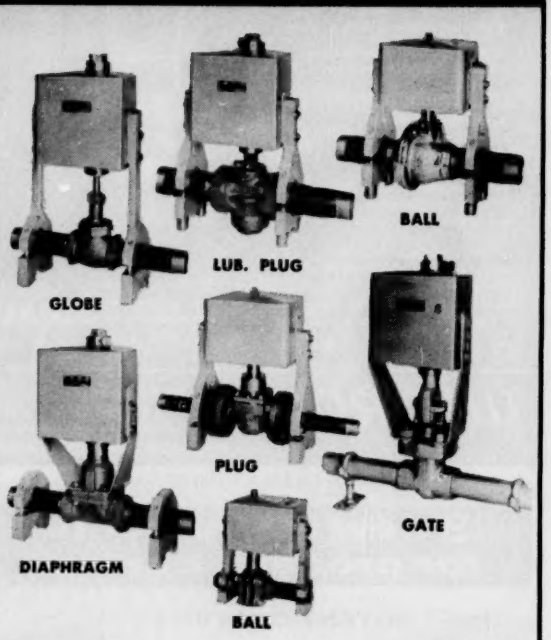
CIRCLE 146 ON READER-SERVICE CARD

R & A

Electric Valve Actuators

OPERATE

All Types of Valves!



Available in a wide range of torques and time cycles, these direct or remote-controlled actuators can be easily installed on existing valves without disturbing operation. Their unique construction minimizes maintenance cost. Their use permits a full range of metering and flow control.

LOW COST MAKES COMPLETE VALVE AUTOMATION PRACTICAL!

Why put up with more expensive and more limited pneumatic actuators! Now you can move up to full valve automation at ½ the competitive cost per inch pound of torque!

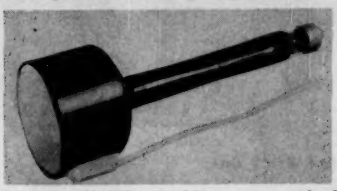
FOR PRICE LIST AND DESCRIPTIVE MATERIAL, WRITE OR CALL

R & A MACHINE CO., Inc.
100 GROVE ST. WORCESTER 5, MASS.

CIRCLE 147 ON READER-SERVICE CARD

HIGH-RESOLUTION CR TUBE

New 5" EAI-Type 5CKP one-mil spot size magnetic focus and deflection Cathode-Ray Tube features minimum particle size phosphor screen



with negligible voids, an optical-quality flat face-plate. Typical operating conditions include: Accelerator voltage—20,000 vdc; grid No. 2 voltage—1,000 vdc; grid No. 1 voltage—−35 to −100 vdc.—*Allen B. Du Mont Labs., Inc., Electronic Tube Sales Dept., Clifton, N. J.*

CIRCLE 210 ON READER-SERVICE CARD

CURRENT INTEGRATOR

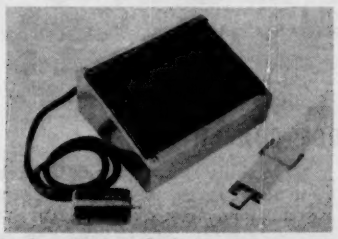
New Current Integrator Model CI-110, simultaneously measures (1) an instantaneous current from 0.003 μa

to 1 ma and (2) the time integral (total charge) of this current. Features include modular packaging with all basic elements mounted on plug-in circuit cards. Advance Data Sheet contains details.—*Eldorado Electronics, 2821 Tenth St., Berkeley 10, Calif.*

CIRCLE 211 ON READER-SERVICE CARD

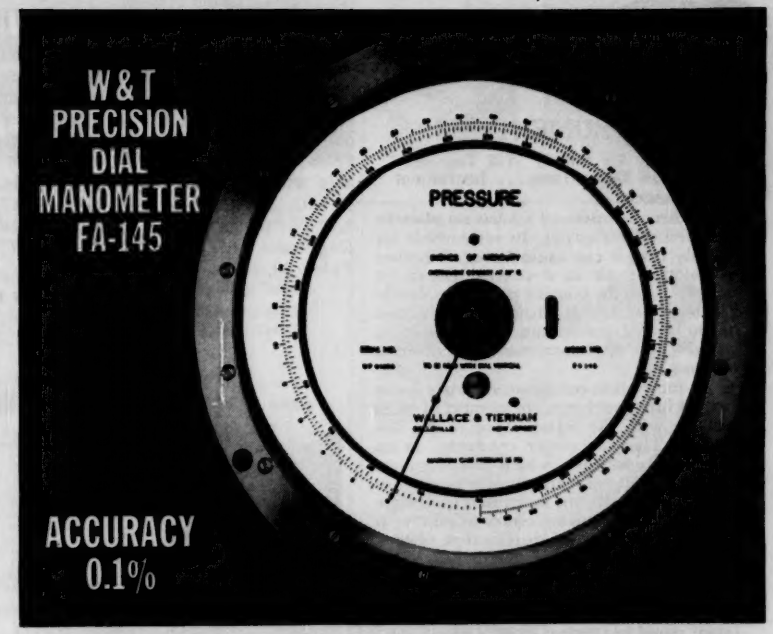
FUNCTION GENERATOR

New Vernistat-Adjustable Function Generator operates essentially as an adjustable non-linear potentiometer, and produces any curve, mathematical or empirical, with 34-chord accuracy. Curves may be generated



singly with ten shaft turns, or as continuous repetitive functions with unidirectional shaft rotation. The curve being generated is displayed in rectangular coordinates with out-put voltage as the abscissa and shaft position as the ordinate. Generator is composed of a function-adjusting assembly and a cable-connected interpolating Vernistat.—*Vernistat Div., Perkin-Elmer Corp., Norwalk, Conn.*

CIRCLE 212 ON READER-SERVICE CARD



PRECISION PRESSURE Measurement
of Gauge, Vacuum or Differential Pressures on Pneumatic Systems

Accuracy:	1/1000 of full scale
Sensitivity:	1/10,000 in *all* ranges
Ranges:	0 to 120 inches of water (min.) 0 to 300 inches of mercury (max.) Other intermediate ranges available
Scale Length:	45 inch scale in two revolutions
Dial Size:	8½ inches

Write for Publication No. A-109.48

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MANOMETERS—CIRCLE 100 ON READER-SERVICE CARD
FEEDERS—CIRCLE 101 ON READER-SERVICE CARD

ADAMS FACT FILE #3

INSTRUMENT AIR

Clean Dry Air Supply Will Reduce Production Down-Time . . . Instrument Maintenance . . .

Wet, dirty compressed air has no place in the process industries. In instrument air supply lines it can cause havoc. Whether it be motor air in a control circuit or supply air to the control panel, absolutely clean dry air is vital. Moisture elimination is the major consideration in providing suitable air for instrument and control systems.

Since most plant compressors in use today are oil lubricated, a finite amount of oil is present with the water vapor in the discharge. This carry-over condenses as an oil-water emulsion which often causes serious fouling of instrument components. To eliminate this oil-moisture condensate in the air lines, it is necessary to remove it before it reaches the distribution system. This is done by cooling the air before the receiver. It is advisable to cool well below the ambient conditions to provide the lowest possible humidity at the instrument panel or control units.

Two Stage System Design for Economy

The ideal method to achieve high quality air is a two-step operation.

1—An Adams Aftercooler . . . providing 2° F. cooling . . . and Cyclone Separator installed between the compressor and receiver to remove the bulk of moisture carry-over.

2 — A chemical dryer installed down stream to provide the polishing action necessary for the desired minimum humidity.

Thus, the bulk of water . . . 90% . . . is removed by the Aftercooler-Separator using plant water for cooling. A minimum moisture load is then left to be removed by more expensive methods. Under normal circumstances, all of the oil present in the compressor discharge will be removed in the Aftercooler-Separator. Fouling of the chemical unit is then virtually eliminated.

Poro-Stone Air Filter at Panel Provides Dirt-Free Control Air . . .

In spite of the efficiency of the Adams Aftercooler and Separator, there still will be some dust and dirt present in the instrument air system. That's why it is advisable to install an Adams Poro-Stone Air Filter in the line just before the control panel.

Separation by the Adams unit is in two stages — centrifugal and diffusion. Centrifugal force throws the foreign matter to the walls of the filter body where it is trapped in slots and drained. Remaining particulate matter is removed as the air passes through the pores of the Poro-Stone element.

This final protection for your instruments will minimize control system failures and process down-time. Instrument maintenance will be sharply reduced.

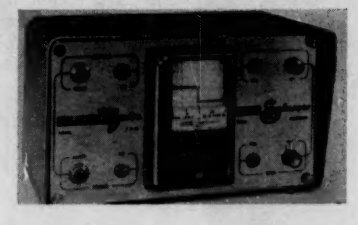
Literature Will Help Air System Design

For further information on how the complete line of Adams air equipment can help you provide a foolproof instrument air supply, write today for your copy of Bulletin No. 712 on Aftercoolers and Separators and Bulletin No. 117 on Poro-Stone Air Filters to the R. P. Adams Company, Inc., 265 East Park Drive, Buffalo 17, New York.

CIRCLE 102 ON READER-SERVICE CARD

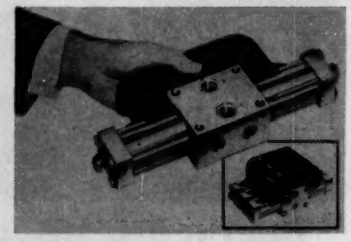
DIELECTRIC MONITOR

New Dielectric Monitor, Model T.D.M., is a precision capacitance-type monitor specifically designed for L.A.C.T. systems. Completely transistorized, the unit is provided with 31-day strip-chart recording. Available with high- or low-limit controls, or both. Accuracy is rated better than 0.1% in terms of B.S. & W.—*United Engineers, Inc., 824 E. Sixth St., Tulsa 20, Okla.*



CIRCLE 213 ON READER-SERVICE CARD

4-WAY A-C SOLENOID VALVES

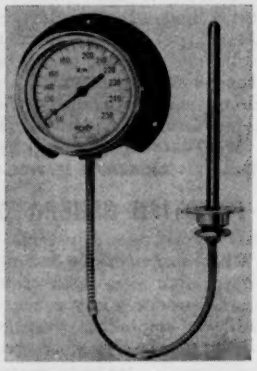


New line of 4-way A-C Solenoid Valves features unusually low pressure drop (about 60 psi at 5 gpm); an exclusive design which has eliminated inrush current; totally enclosed working parts; static seals that are compatible with all petroleum-base fluids; and easy stacking or banking, without the use of special base plates or manifolds.—*Waterman Hydraulics Corp., 725 Custer Ave., Evanston, Ill.*

CIRCLE 214 ON READER-SERVICE CARD

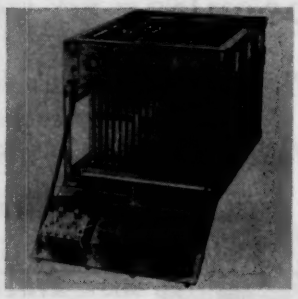
VAPOR THERMOMETERS

New insertion-type, vapor-actuated dial Thermometers for duct installations are enclosed in black enameled aluminum cases with brass slip rings, furnished with a sensitive 6" or 12" air bulb with a union connection flange to prevent air leakage, and an extension neck where insulation is present. Patented adjust-angle can be changed to permit revolving the case for the best vision by a simple adjustment of the lock nut for the stem. Sizes: 3½", 4½", 6" and 8" dials. Std. Ranges: −40/65°F, −20/120°F, 0/100°F, 30/150°F, 40/220°F, 60/250°F, 100/350°F.—*Weksler Instruments Corp., 195 East Merrick Rd., Freeport, L. I., N. Y.*



CIRCLE 215 ON READER-SERVICE CARD

TRANSISTORIZED CODE CONVERTER



New fully-transistorized Digital Computer, the AN/UGA-3, (commercial nomenclature CMP-18) automatically copies Morse code and converts it into teleprinter code at a rate of from 10 to 120 words/min, then types message on a page-copy teleprinter. Adjusting automatically to changes in speed of transmission, it demodulates noisy signals, and maintains the associated communications receiver tuned to within 5 cycles of the signal being received.—*CGS Laboratories, Wilton, Conn.*

CIRCLE 216 ON READER-SERVICE CARD

FOR RELIABILITY... FOR QUALITY... FOR SERVICE

Specify

KURMAN RELAYS

Immediate delivery from stock at factory prices thru

KURMAN SALES AGENCIES

These leading Distributors — Kurman SALES AGENCIES — stock our complete line

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Radio Equipment Corp., Buffalo
Schenectady Electronic Dist. Corp., Schenectady
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SOUTHEAST
Electra Distributors, Nashville, Tenn.
Electronic Equipment Co., Miami, Fla.
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Ballard Supply Co., Ogden
C & G Radio Supply, Seattle, Centralia, Tacoma, Bremerton, Olympia, Aberdeen
Dean Electronics, Long Beach, Calif.
Frank Quement, Inc., San Jose
Sacramento Electronic Supply, Sacramento
Silvergate Radio Supply, San Diego
Tel-Electric Distributors, Inc., Spokane
Universal Radio Supply Co., Los Angeles

Shown here are only a few of the many KURMAN RELAYS stocked by the leading distributors throughout the country.

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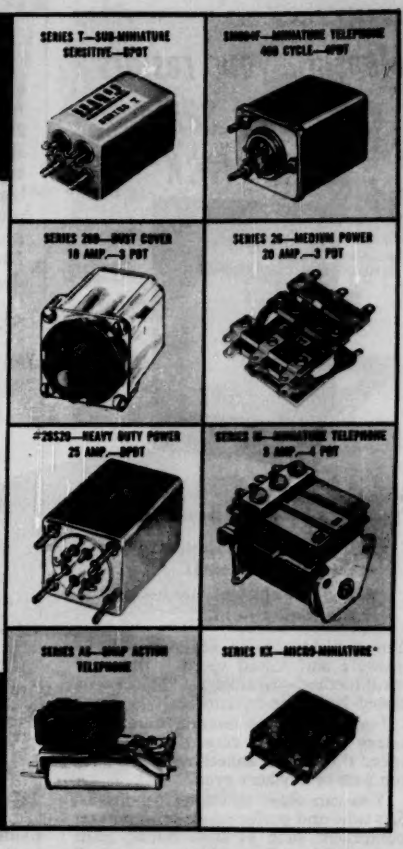
See our catalog pages in the Radio-Electronic MASTER

Contact your Sales Agency or factory for your specific requirement and FREE "Quick-Find" Relay Spec. Chart.


SERIES T—SUB-MINIATURE SENSITIVE—SPDT
SERIES 200—DUST COVER 10 AMP.—3 PDT
SERIES 26—MEDIUM POWER 20 AMP.—3 PDT
#26529—HEAVY DUTY POWER 25 AMP.—SPDT
SERIES AS—SNAP ACTION TELEPHONE
SERIES KX—MICRO-MINIATURE

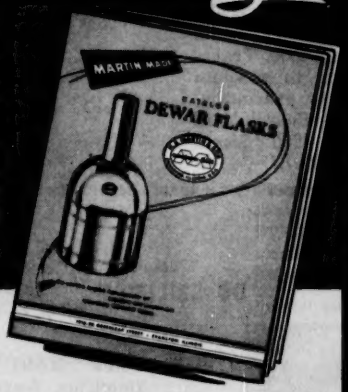
KURMAN ELECTRIC CO.

191 Newel St., Brooklyn 22, N. Y.

CIRCLE 103 ON READER-SERVICE CARD

Announcing

A NEW 54-PAGE CATALOG OF DEWAR FLASKS



The most comprehensive listing of standard and special Dewar flasks ever published.

A large variety of standard flasks is listed that can be supplied from stock for both regular laboratory use and cryogenic research. Also included are many possible variations which can be produced to aid your engineers in designing special shapes for work in the low temperature fields with liquid hydrogen and helium. MARTIN-MADE Dewar flasks are highly evacuated at high temperatures and all are manufactured without separation pads. Write today for your copy.

H. S. MARTIN & SON

1916-20 GREENLEAF STREET • EVANSTON, ILLINOIS

SCIENTIFIC GLASSWARE OF SUPERIOR QUALITY

CIRCLE 104 ON READER-SERVICE CARD

PRECISION JEWEL BEARING ASSEMBLIES . . .

for AIRCRAFT • ELECTRICAL MECHANICAL and MARINE INSTRUMENTS

Sapphires set in brass, or other metal assemblies made in any quantity to close tolerance specifications are produced by Moser Jewel Company—*manufacturers of industrial jewels for over 50 years.*

Moser also provides highly polished pivots, staffs —silicon and spring loaded assemblies for high shock resistance.

SEND SPECIFICATIONS — DETAILED INFORMATION READILY GIVEN.

MOSER JEWEL COMPANY

P.O. Box 150 • Perth Amboy, N. J.

"Manufacturers of all types of Industrial Jewels"

CIRCLE 105 ON READER-SERVICE CARD

Measure your results with this SPEED "YARDSTICK"

Speed is one of your most valuable "yardsticks" in the measurement of

- ★ **rate of production,**
- ★ **quality of product,**
- ★ **performance of machinery and equipment.**

The simplest, most accurate way to measure and record speed is the electrical method—with an Esterline-Angus Speed Recorder System.

For example, you can determine processing time with a record of conveyor speed through an annealing lehr, a plating bath or a bakery oven.

You can chart operating conditions, lost time and performance of important equipment such as steel rolling mills and machines for making paper, wall board, roofing, felt, textiles, etc.

Steam turbines, pumps, blowers, presses and marine engines are others among a multitude of machines where a record of speed is important.

In the Esterline-Angus Speed Recorder System, an E/A Tachometer Generator (pictured here), actuates an E/A strip-chart Speed Recorder (above) to give you an indisputable record, free of human bias and error.

Like all Esterline-Angus graphic instruments and accessory equipment, the Tachometer Generator and the Speed Recorder are ruggedly built for accuracy and dependability over a long and useful life.

Send for Catalog Section 46 and see how the E/A Speed Recorder System can help you.

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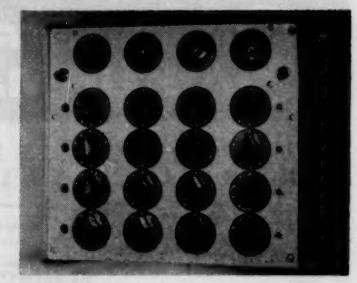
CIRCLE 106 ON READER-SERVICE CARD

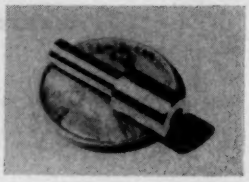
PRESET COUNTERS

New 2000 Series Preset Counters are available from 3 to 6 digits, and from 1 to 6 preset banks. The Model 2044, 4-digit and 4-bank counter is shown. Features include: All-electronic circuitry, completely transistorized design, solid-state power supply, plug-in output relay, cold-cathode counting tube elements, reinforced fiberglas cabinet, and low power drain, less than 10 w at 115 vac.—*Oxford Engineering Co., 47A River St., Wellesley Hills 81, Mass.*



CIRCLE 217 ON READER-SERVICE CARD

SUB-MIN THERMOWELL

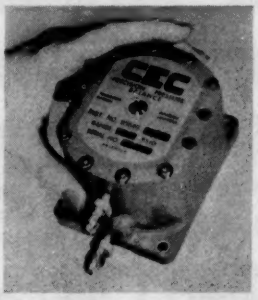


New sub-miniature Thermowell with an overall length of $\frac{13}{16}$" and 15/32" immersion is made of stainless steel and has a 0.093" bore concentric within 0.001" for a high degree of accuracy as well as maximum protection.—*Trinity Equipment Corp., Cortland, N. Y.*

CIRCLE 218 ON READER-SERVICE CARD

PRECISION PRESSURE BALANCE

New miniature Type 4-332 Precision Pressure Balance for use with the Electromanometer precision pressure measuring system measures only 4" x 3" x 2½" and weighs 2.6 lb. Made in seven ranges, from 0 - 1½ to 0 - 150 psi differential. Output of the transducer is ±100 v full scale. Combined effects of linearity and hysteresis are less than 0.05%. Transducer can be converted to absolute pressure measurement by evacuating the reference inlet.—*Consolidated Electrodynamics Corp., 260 Sierra Madre Villa, Pasadena, Calif.*



CIRCLE 219 ON READER-SERVICE CARD

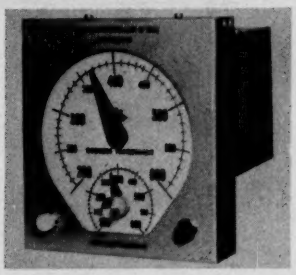
DC AMLIFIER

New Model 93 solid-state D-C Amplifier, featuring a unique combination of differential input and wide bandwidth, can drive any of the new high-frequency galvanometers. Its maximum current output is 100 ma at an output impedance of less than one ohm. Input impedance is higher than 50K ohms, isolated by at least 100 megohms from the cabinet. The recovery time from overloads is 100 msec max. Has an integral, regulated power supply.—*Video Instruments Co., Inc., 3002 Pennsylvania Ave., Santa Monica, Calif.*

CIRCLE 220 ON READER-SERVICE CARD

TEMPERATURE CONTROLLER

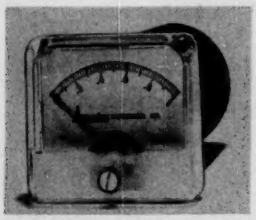
New Series 6000 Indicating Temperature Controller features a 12" circular readout based on a rugged stable null-balance servo system. Mode of control is either time proportioning, or on-off, with or without anticipating section. Control stability of the proportional model with anticipating section has been achieved to ±0.1°F, and to ±0.5°F with the on-off model with anticipation. Indication accuracy is ±1% of scale range.—*Electronic Processes Corp. of Calif.*, 436 *Bryant St., San Francisco 7, Calif.*



CIRCLE 221 ON READER-SERVICE CARD

PULSE RATE INTEGRATOR

New transistorized Pulse Rate Integrator, Model PI-100, which indicates frequency or pulse rate from transducers such as flow meters, tachometers, and similar frequency signal sources, is combined with an integrally-mounted 2½" D'Arsonval indicator. Output is a function of frequency alone and does not vary with the amplitude of the input signal. Features include high accuracy and extremely low power drain.—*Anadex Instruments, Inc.*, 14734 *Arminta St., Van Nuys, Calif.*



CIRCLE 222 ON READER-SERVICE CARD

LOW-COST COUNTER

New Electromagnetic Counter displaying six digits, is a low-speed, limited-life unit of minimum initial cost, 2.092" wide, 2.401" high, and 2.250" deep, including the 4-hole mounting flange, or base. Wheels are white die-cast metal with black, 0.188"-high characters. Operation from 115-v ac or on other a-c or d-c voltages as special. Power consumption is approximately 6 w. Maximum constant speed rating is 700 counts/min.—*Veeder-Root, Inc., Hartford 2, Conn.*

CIRCLE 223 ON READER-SERVICE CARD

DIGISYN® ENCODERS

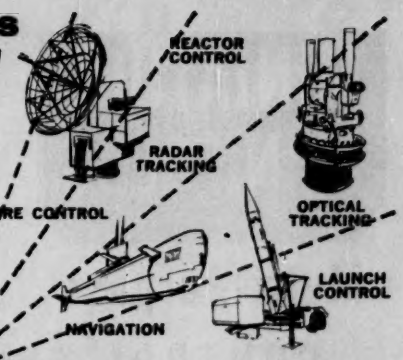
for precision in:

Radar and Optical Tracking

Navigation and Guidance Systems

Missile Launch Control

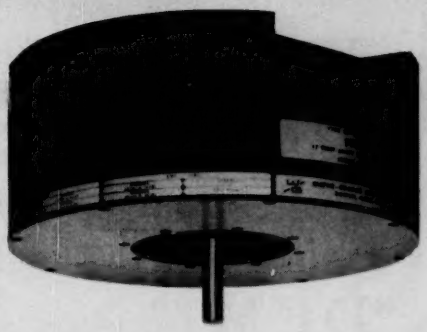
Nuclear Reactor Control



W-G

NEW RD-17

Photoelectric Shaft Position Encoder



DIGISYN® RD-17

The Ultra-Precise Encoder

- 17-digit accuracy in 10" diameter — 10-second resolution without gearing
- Self-contained amplifiers and control electronics
- Self-contained power supplies — 115 Volts, 60 cps or 400 cps input power
- Solid or Hollow Shaft Input
- Serial or Parallel Digital Readout
- Modular construction — easy maintenance

When you need the ultimate in accuracy, the utmost in reliability, the maximum in performance, the minimum in maintenance — specify DIGISYN® Shaft Position Encoders. They provide a direct, single-step method of digitizing the angular position of a shaft, meet military specifications, and function in environmental extremes.

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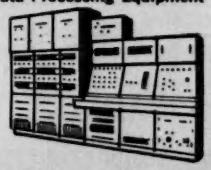
Standard & Custom Encoders

Data Processing Equipment



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CIRCLE 107 ON READER-SERVICE CARD

MINIATURE MANIFOLDS for

Multi-Purpose CONTROL

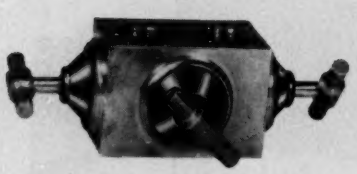


Photo ½ actual size

PACKLESS

"DEMI" M2 SERIES

All models of the standard Dahl "Demi" M2 series of three-valve manifolds are readily adaptable to clean liquid, gas and vapor applications. The size of these manifolds makes them especially suitable for pilot plant, aircraft and marine applications, flow control and automation. They are miniature in size, yet their patented form for bubble-tight shutoff makes them comparable to much larger valves in performance.

These manifolds consist of two block valves and one bypass valve in place of 3 separate valves . . . they eliminate two tees, four nipples and eight threaded connections. Models of the "Demi" M2 series come in a variety of barstock materials and may be ordered with special features such as: bolted bonnets, swaged-in TEFLON seats, toggle actuators, etc.

PRESSURE RATING Metal Body & Diaphragm Neoprene Diaphragm	 750 psi at 450°F 100 psi at 180°F
MAXIMUM Cv	0.4
CONNECTIONS	1/16", 1/8", 1/4" N.P.T.

Send for the "DEMI" Catalog D-1 and other technical data on Dahl pneumatic and hydraulic valves.

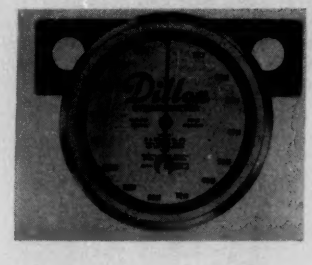
GEORGE W. DAHL COMPANY, INC.

86 TUPELO STREET, BRISTOL, RHODE ISLAND

CIRCLE 108 ON READER-SERVICE CARD

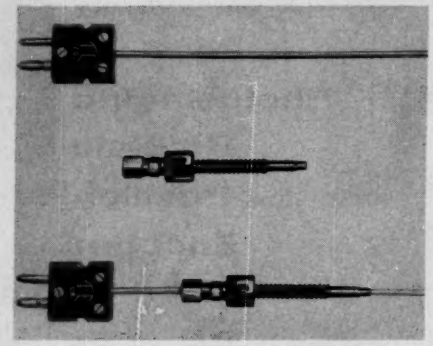
DIRECT-READING DYNAMOMETER

New direct-reading, traction-type Dynamometers with capacities of 150,000 and 200,000 lb have highly visible 10"-dia dials. Features include resetable red maximum hand which "remembers" point of peak load; ultra-sensitive mechanism which produces a full-scale reading with only 0.040" deflection of the special alloy steel beam regardless of capacity; individual calibration to an accuracy of ±2% of full range.—*W. C. Dillon & Co., Inc.*, 14620 *Keswick St., Van Nuys, Calif.*



CIRCLE 224 ON READER-SERVICE CARD

THERMOCOUPLE ADAPTER

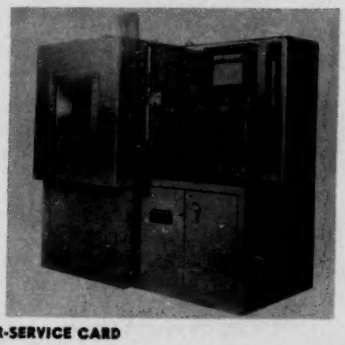


New Thermocouple Adapter converts a ⅛" or $\frac{1}{16}$" Ceramo (or other metal-sheathed tubular type thermocouple) to a spring-loaded thermocouple with an adjustable immersion length from 1" minimum. Constructed of a s-s. sheath and cap, Inconel X or s.-s. spring, a nickel-plated brass compression fitting and a brass or nylon ferrule, the brass ferrule provides a permanent immersion setting while the nylon ferrule allows for adjustment of the immersion length.—*Thermo Electric Co., Inc., Saddle Brook, N. J.*

CIRCLE 225 ON READER-SERVICE CARD

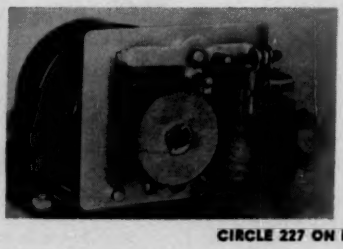
TEST CHAMBER

New 27-cu-ft altitude Test Chamber, Model FH-27, features strip-chart recording/controlling of temperature (standard ranges are −100°F to +300°F, or to +500°F); cooling rates: to −70°F in 38 min; heating rates: from −70°F to ambient in 14 min, from ambient to +300°F in 20 min, and to +500°F in 45 min; potentiometer electronic recording controller for altitude.—*Conrad, Inc.*, 141 *Jefferson St., Holland, Mich.*



CIRCLE 226 ON READER-SERVICE CARD

MOTOR BRAKE



New low-cost precision-built brake for fhp motors has a braking torque of 2 to 4 in-lb for shafts up to ⅜". Without load the motor is stopped in less than ¼ rev.—*Midwest Automatic Control Co.*, 510 *Third St., Des Moines* 9, *Iowa.*

CIRCLE 227 ON READER-SERVICE CARD

New Clevite Accelerometers!

500°F Operation
3% Lateral Sensitivity
50kc 1st Resonance
1600 mmfd. Internal Capacity

Stock Sizes: 5 mv/g
10 mv/g, 20 mv/g

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CIRCLE 110 ON READER-SERVICE CARD

Synchro-Start
FULL AUTOMATIC ENGINE CONTROLS
FOR GASOLINE DIESEL & GAS ENGINES

Synchro-Start's new protective engine controls have been designed, for the starting and stopping of engines from remote pilot devices, such as pressure switches, float switches, power failure relays, etc., and are completely automatic in operation.

These dependable controls are encased in a steel, dust proof cabinet, and now feature enclosed PLUG-IN RELAYS as well as OVERLOAD BREAKERS. The plug-in relays simplify what little field maintenance that may have been required in older models, while the overload breakers eliminate the necessity of replacing fuses.

In designing this unit we have used the same high quality materials and workmanship that our customers have come to expect throughout Synchro-Start's 27 years of manufacturing engine controls.

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Today's Modern Industry
Demands a Modern Thermometer

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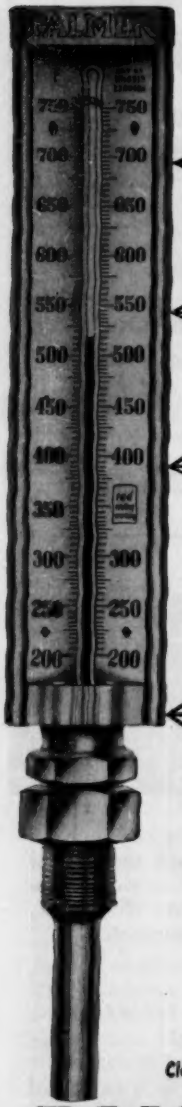
RED-READING MERCURY THERMOMETERS



Red-Reading Mercury

Extruded Brass Case

Chrome Finish

Ranges −40 to 950°F or Equivalent in °C

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THERMOMETERS, INC.
Mfrs. of Industrial Laboratory, Recording and Dial Thermometers
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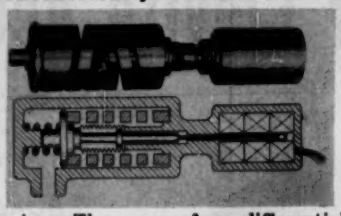
CIRCLE 112 ON READER-SERVICE CARD

PRESSURE TRANSMITTERS

New series of Pressure Transmitters has linear electrical output. Sensing element consists of a bellows concentrically mounted within a



spring. The core of a differential transformer, built into the unit, moves with a shaft. Units are available for ranges from 0 to 2,500 psi, 0 to 500 psi, and 0 to 1,500 psi. Overrange protection to 3,750 psi is provided. Output voltages can be either ac or dc. On a-c models, input voltage is 6 v/60-cycle a-c with a power consumption of approximately one w; a-c outputs vary with pressure from 0 to ½ v. Accuracy of the units is ±¾%.—*Consolidated Controls Corp., Bethel, Conn.*

CIRCLE 228 ON READER-SERVICE CARD

MINIATURIZED ELECTROMETER

New Model E-105 Electrometer measures d-c current levels to 2×10^{-14} amp. General specifications—sensitivity: 10^{-12} amp, full scale; drift: less

than 2% full scale per week on 10^{-11} amp or greater; noise: less than 2% full scale for current ranges from 10^{-11} amp or greater; accuracy: 2% full scale from 10^{-9} to 10^{-7}; other ranges within 3% full scale; input drop: less than 6 mv; recorder output: 10 mv; power: 105 to 125 v/60 cycles; 30 w consumed.—*Gyra Electronics Corp., Box 184, LaGrange, Ill.*

CIRCLE 229 ON READER-SERVICE CARD

MANUALLY CONTROLLED LENS

New manually controlled zoom Lens for Vidicon cameras, MARK VI-M,

with a zoom range of 6:1 is a version of the MARK VI remote-controlled unit for ITV. Specifications include—focusing range: 8′ to infinity; resolution: 800 TV lines; coverage: ⅝″ diagonal.—*Zoomar, Inc., Glen Cove, L. I., N. Y.*

CIRCLE 230 ON READER-SERVICE CARD

THERMAL CONDUCTIVITY EQUIPMENT

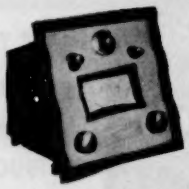
Therma Bridge GAS ANALYZER

For monitoring purity values in gas streams and for wide applications in gas impurity analysis. Completely self-contained unit with sensing cells, precision machined gas trains, newly designed dessicant drier columns, control circuit and power supply. Functionally designed with all controls located in convenient positions.

Therma Bridge SENSING CELLS

Advanced design provides greater output response. Available in two metal mass weights. Heavyweight, open-core, hexagonal cell and light-walled, individual cavity type. All units provide low background noise, super-smooth electrical balance, improved sensitivity and heat transfer.

Therma Bridge POWER SUPPLY



Power supply and control circuit unit readily adaptable as a power source for any thermal conductivity sensing cell or for any other requirement demanding a precisely regulated output voltage and currents between 30 and 500 milliamperes. Unit utilizes selenium rectifier full wave bridge circuit with high efficiency transistorized error amplifiers.

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CIRCLE 113 ON READER-SERVICE CARD

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MAGNETIC GAGE

for liquid levels

An important advancement in liquid level observation for plants with dangerous explosive or inflammable conditions.

Safety design seals against escaping gases.

Measuring mechanism in stainless steel chamber.

Scale mounted outside chamber; magnetically actuated through chamber wall.

Distinct, accurate level shown in red contrasted with silver above.

Job designed, correlating pressure, temperature, and specific gravity.

Available with electric alarms.

Can also be used for interface indication.

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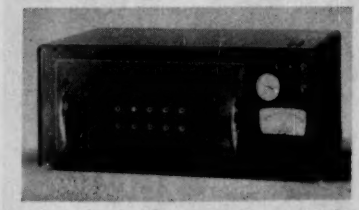
CIRCLE 114 ON READER-SERVICE CARD

PORTABLE TEMP CHAMBER

New 1060 Series Portable Temperature Chamber maintains temperatures within ±0.2°F over a range of −100°F to +500°F. This control is accomplished by a meter-relay in

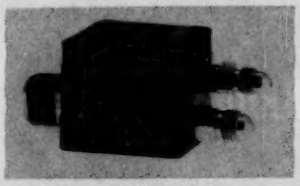


conjunction with a copper-constantan thermocouple. Rack-mounted model and two bench models have test volume of 10" x 7" x 7"; drawer model has test volume of 16" x 7" x 7". Liquid CO_2 automatically cools three of the new chambers, while dry ice (solid CO_2) is used in the fourth chamber. Heating is accomplished by 650-w electric elements.—*Delta Design, Inc., 7460 Girard Ave., La Jolla, Calif.*

CIRCLE 231 ON READER-SERVICE CARD

HIGH-G-LEVEL PRESSURE TRANSDUCER

New potentiometric-output-type Pressure Transducer, Model 100, capable of performance under high-



G-level environment (to 50 G's at 3 Kc) and yielding infinite resolution, is available for pressure ranges from 0-15 to 0-300 psi for corrosive and non-corrosive liquids and gases.—*White Avionics Corp., Terminal Rd., Plainview, L. I., N. Y.*

CIRCLE 232 ON READER-SERVICE CARD

PRECISION AC POT

New Series 2 Vernistat Precision A-c Potentiometer features a precision shaft coupling for gear-coupling of the component to other ele-

ments in a system. Characteristics include linearities from ±0.05%, output impedances from 45 to 470 ohms, input impedances from 65,000 to 200,000 ohms, and extremely low phase shift. The ten-turn "Vernistat" operates at 130 v at a nominal 400-cps input.—*Perkin-Elmer Corp., Vernistat Div., Norwalk, Conn.*

CIRCLE 233 ON READER-SERVICE CARD

AMERICAN®

PRESSURE and TEMPERATURE RECORDERS

American® single and two-pen Pressure Recorders for pressures from 30 inches vacuum to 10,000 psi.

- Pressure elements individually calibrated over full range.
- Variety of chart drives available.
- Helical elements of different ranges are interchangeable.
- Stainless steel pen arms with span and linearity adjustments.
- Aluminum dust and moisture-proof case.

American® *Temperature Recorders* for an accurate record of flowing temperatures.

- No ambient temperature errors.
- High sensitivity and torque—fast speed of response.
- Standard 0-150°F. range. Other ranges available by request.
- 24-hour mechanical or 110-v, 60-cy. electric chart drives.

Ask for Bulletins 400 and 408

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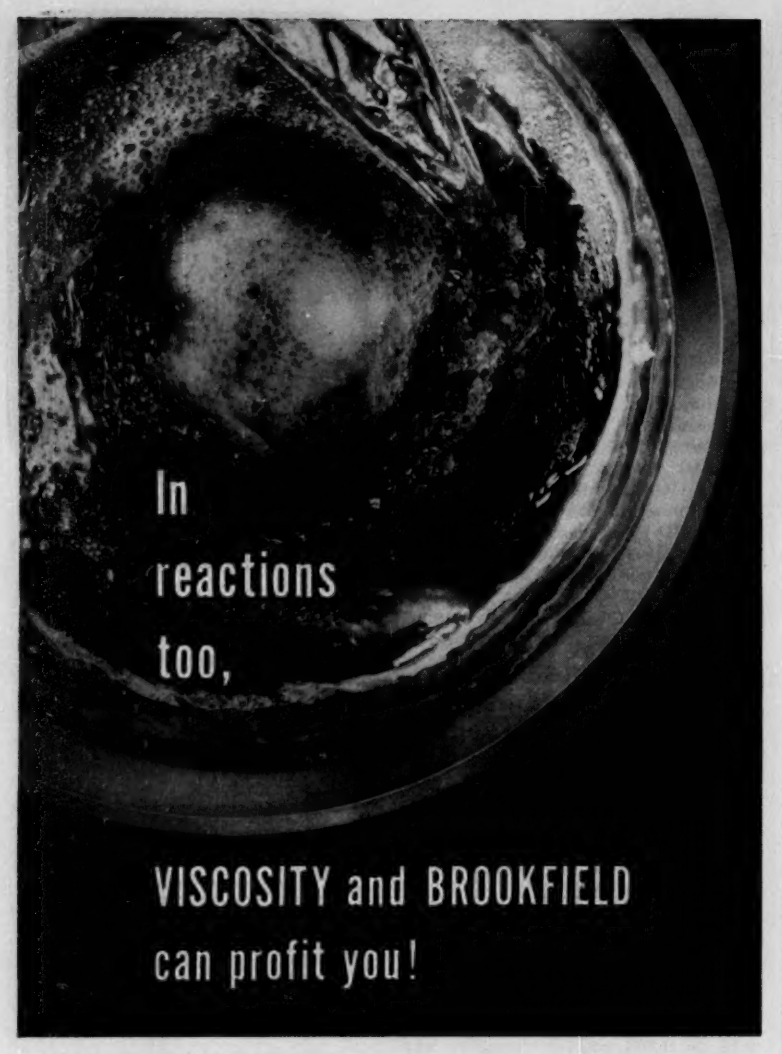
CIRCLE 115 ON READER-SERVICE CARD



It's true. In-process viscosity measurement is the most direct progress report of many chemical reactions that you can obtain. In polymerization reactions, for example, Brookfield process-mounted Viscometran units eliminate the need for constant sampling, assure greater product uniformity and guard against run-away reactions.

Like color, pH and stability the *viscosity* of any material is a vital property, a fundamental measurement, which can be easily and accurately evaluated and controlled with low-investment Brookfield instrumentation.

If you would like to know more about the profitable role of viscosity control in your processes, write today for complete technical information. There is no obligation.

THE WORLD'S STANDARD FOR VISCOSITY MEASUREMENT AND CONTROL

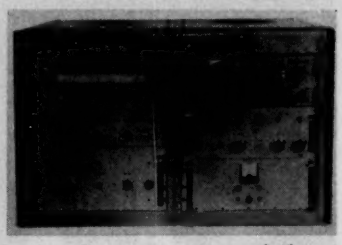
Brookfield

ENGINEERING LABORATORIES, INCORPORATED
STOUGHTON 316, MASSACHUSETTS

CIRCLE 116 ON READER-SERVICE CARD

ANALOG COMPUTER

New electronic Analog Computer, Model CF-1, is especially designed to solve Fourier integrals. Amplitude and phase input functions are taken off the graph with a photoelectric reader, passed through a pulse-posi-

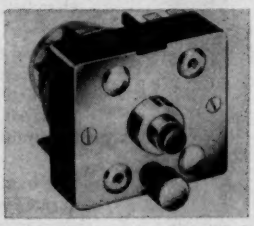


tion-to-voltage converter and then to appropriate computing circuitry. Integration can be observed on a d-c oscilloscope for interpretation or visual readout. Final recording uses maker's antenna patern recording equipment.—*Scientific-Atlanta, Inc.*, 2162 *Piedmont Rd., N. E., Atlanta* 9, *Ga.*

CIRCLE 234 ON READER-SERVICE CARD

PUSH-BUTTON TIMERS

New push-button-actuated adjustable Interval Timer, Series AT-36, is a totally-enclosed, motor-driven device for the control of fans, vending machines, mixers, photocopying equip-

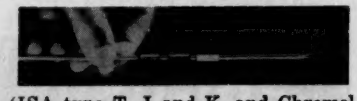


ment, etc. Equipped with "Ark-Les" quick-disconnect type terminals for rapid, easy hook-up and ready replacement or repair. Available for 120- or 240-v operation at 50 or 60 cps with intervals of 30 sec and 1, 5, 10, 30, 60 or 120 min.—*Haydon Div. of General Time Corp.*, 245 *East Elm St., Torrington, Conn.*

CIRCLE 235 ON READER-SERVICE CARD

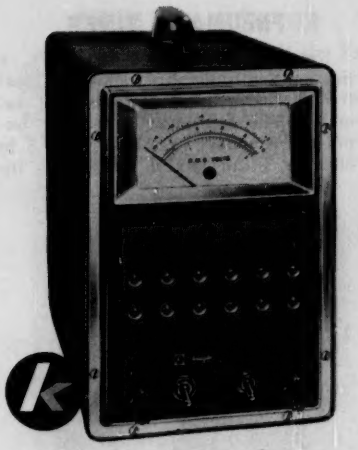
INSULATED T/C WIRE

New type Insulated Thermocouple Wire termed Insupack, is conventionally-insulated small-diameter type, sheathed in metal tubing. Available in all base metal calibrations



(ISA type T, J and K, and Chromel-Constantan) in single or duplex pairs. Standard wire diameters are $\frac{1}{8}$", $\frac{3}{16}$" and $\frac{1}{4}$" with Fiberglas, Teflon, polyvinyl, or Refrasil insulation. Copper, 304 stainless steel, and Inconel are standard sheaths.—*Pryometer Co. of America, Inc., Penndel, Penna.*

CIRCLE 236 ON READER-SERVICE CARD



This is the new ***knight-kit*** **ac vtvm.** It marks a major achievement in instrumentation...and a break-through in the professional instrument price barrier. Here is the only vtvm with **automatic range selection**... featuring a self-seeking mechanism which automatically selects the proper range when probes are touched to the circuit under examination. Simultaneously, a front panel light indicates the range in use. There are 11 ranges from 3 millivolts to 300 volts full scale; frequency response to 2.5 mc. Reads as low as 100 μv. This precision instrument is an exclusive ***knight-kit*** development, designed for easy assembly. There is nothing like it on the market, in any form or at any price. Available only from Allied Radio.....**$99.50**

only $5.00 down

you'll find the detailed specifications here

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See the complete Knight-Kit line for professional and home use. Includes scores of instrument, hi-fi, Amateur and hobbyist kits—best by design—the most for your money. For everything in Kits, for everything in Electronics, get the Allied 1960 Catalog. Send for FREE copy today.

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CIRCLE 117 ON READER-SERVICE CARD

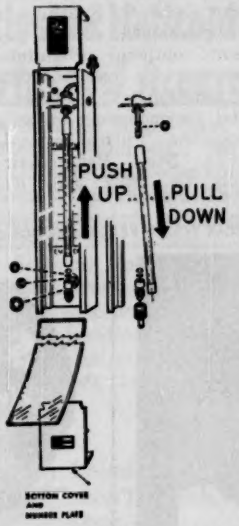
LOW-PRESSURE TRANSDUCER

New high-accuracy Compu-tran Low Pressure Cell incorporates a Ni-Span-C capsule as sensing element which completely eliminates linkages, contacts, and other potential sources of trouble. The magnetomotive nature of the differential transformer provides infinite resolution, and the output signal is therefore linear and stepless. Gage-, differential-, and absolute pressures can be measured. Delivering high-level output signals, up to 1.5 vac or up to 100 mvdc with accessory demodulator, available in ranges from 0-1.5 psig to 0-60 psig, and accuracies of up to ±0.15% of full range.—*International Resistance Co., Computer Components Div.*, 401 *North Broad St., Phila.* 8, *Pa.*

CIRCLE 237 ON READER-SERVICE CARD

LEVEL INDICATOR

New Liquid Level Indicator features an easily removable glass

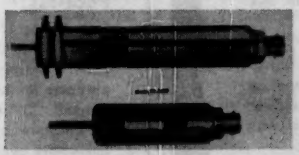


column containing the indicating liquid.—*Petrometer Corp.*, 43-22 *Tenth St., Long Island City* 1, *N. Y.*

CIRCLE 238 ON READER-SERVICE CARD

DISPLACEMENT TRANSDUCERS

New Displacement Transducers, Models DT500 and DT2000, measure linear displacement between 0.500"



and +2.000" with a frequency response from 0 to 10,000 cps dependent on the Photocon Dynagage measuring systems.—*Photocon Research Products*, 421 *North Altadena Dr., Pasadena, Calif.*

CIRCLE 239 ON READER-SERVICE CARD

THE FLOW GOES STRAIGHT-THRU

THIS ALL-NEW BROOKS ROTAMETER-TRANSMITTER

no pockets, no elbows to gum up the works!

This is the rotameter-transmitter for your toughest flow-metering jobs. Brooks' new Model 3611-MPTX.

You can use it for slurries, still bottoms, Bunker oils, pthalic anhydrides, tall-oil compounds—virtually any 'problem' fluid.

You can use it for electric transmission, pneumatic transmission, or flow integration—or transmission *and* integration.

Above all, you can use it with absolute confidence.

Have a look at the transmitter's unique magnetic float-position converter, and you'll see why.

Design Specification Sheet DS-361 gives details. Write for a copy.

BROOKS
ROTAMETER COMPANY
260 J STREET
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CIRCLE 118 ON READER-SERVICE CARD

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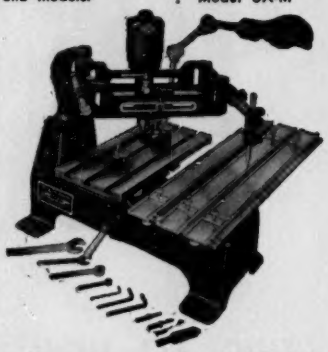
WHAT'S YOUR ENGRAVING PROBLEM

Preis is the "one source" solution for your engraving problems. Complete line of accessories and attachments are available for all makes and models.

- Need greater speed for engraving light and medium characters use Preis-Panto Model UE or UE-2
- Does work require heavy duty machines use Preis-Panto Model UE-3
- Marking metal of extreme hardness, electrical or diamond drag use Preis-Panto UE-M or UM
- Preparing hardened steel or glass for acid etching ask for Preis-Panto Model UA-M



TRADE MARK PANTO

Write for complete details and prices. For immediate attention write directly to manufacturer below. Ask for nearest representative.

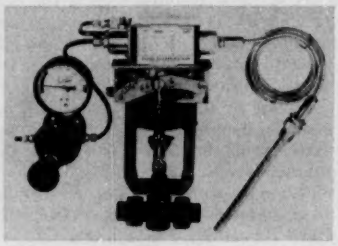
H. P. PREIS ENGRAVING MACHINE CO.
661 U. S. Highway 22, Hillside, N. J.

CIRCLE 119 ON READER-SERVICE CARD

NEW INSTRUMENTS

CONTROLLER UNIT

New FultroMatic Controller-Positioner-Valve combination includes automatic reset. When used as a control

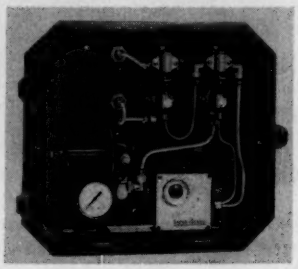


valve (having positive positioner) with various pneumatic transmitters, it can control rate of flow, liquid level, temperatures, or pressures beyond the range of its own vapor-pressure temperature elements or bellows pressure elements. Features include: remote pneumatic control point adjustment; optional all-stainless-steel construction for use in highly corrosive atmospheres; optional indicating dial thermometer; or an electric version, the FultroLectric.—*Fulton Sylphon Div., Robertshaw-Fulton Controls Co., Box* 400, *Knoxville, Tenn.*

CIRCLE 240 ON READER-SERVICE CARD

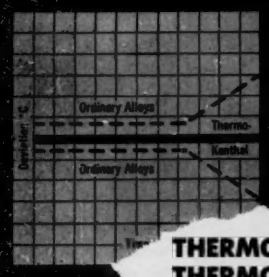
PNEUMATIC TIMER

New Servo-Gauge Oscillator, a pneumatically actuated timer, is ideal for explosive hazard areas and remote field locations. Signaling impulse frequency, variable from 0.3 to 60 cpm, is adjustable within the in-



strument case. Amplitude of the output pressure can be adjusted manually at the instrument or at a remote control center, or automatically by a pneumatic transmitter. Output signal is essentially a rectangular pressure wave having an amplitude of any pressure in the range from 0 to 30 psig. Bulletin P-20 gives details.—*Associated Control Equipment, Inc., Box* 136, *Coraopolis, Penna.*

CIRCLE 241 ON READER-SERVICE CARD



there are many reasons why!

THERMO-KANTHAL THERMOCOUPLES ARE MORE STABLE

Thermo-Kanthal is a product of world recognized Kanthal leadership in special purpose resistance and heating alloys. It is specifically designed to combat the problem of stability with age and use. Particular attention to the composition of the negative leg has resulted in a new order of accuracy and stability, particularly in the 1800°F to 2300°F range.

Thermo-Kanthal couples meet all standard emf curves. No change in instrumentation is necessary. In addition to operating savings, as in less recalibration, Thermo-Kanthal actually costs less initially. Write for data today.

KANTHAL

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CIRCLE 120 ON READER-SERVICE CARD

TYPE M
Solenoid Valves
"We've actually improved quality and radically lowered prices. Compare!"

TYPICAL USER NET PRICES F.O.B. FACTORY

SIZE	1 to 5	100 to 499
½"	$15.40	$11.15
¾"	18.50	13.60
1"	24.25	18.50
1½"	48.00	42.40

PRESSURES TO 400 psi

Packless • 2-Way • General Service • Normally Closed

Sizes ⅜" to 3" • Temperatures to 250° • Molded epoxy resin waterproof coils • Unbreakable piston rings • Self-cleaning • Guided valve seats • Simple, rugged construction. Only 2 moving parts • No diaphragms or linkages • Cushioned closing. No damaging hammer • Easy-off "O" ring bonnet construction in sizes ⅜" thru ¾" • High temperature coils and explosion proof housings at slight extra cost. Immediate delivery. Ask for Bulletin 600-M.

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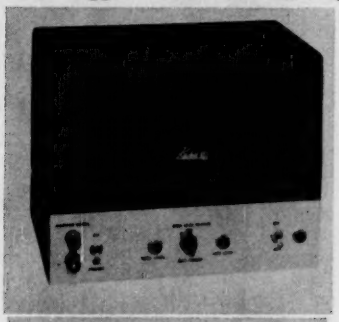
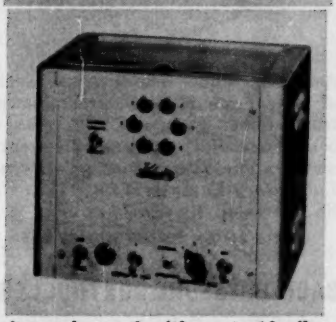
GOULD SOLENOID VALVES VELVETROL

CIRCLE 121 ON READER-SERVICE CARD

VIBRATION MONITOR

New Vibration Monitor, Model KC-524, senses vibration levels in machinery and motors. It consists of two units, a scanning unit which is used with vibration pickups, and an electronic trigger unit. The scanning



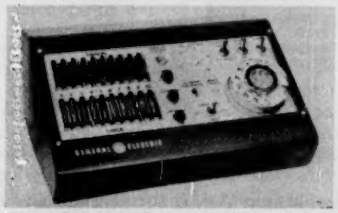


unit can be used with up to 10 vibration pickups. The trigger unit amplifies the vibration signals and feeds them to a trigger circuit and a fail-safe circuit. A shut-down alarm relay is energized when a preset vibration level is reached at any station.—*Kahn and Co., Box* 516, *Hartford* 1, *Conn.*

CIRCLE 242 ON READER-SERVICE CARD

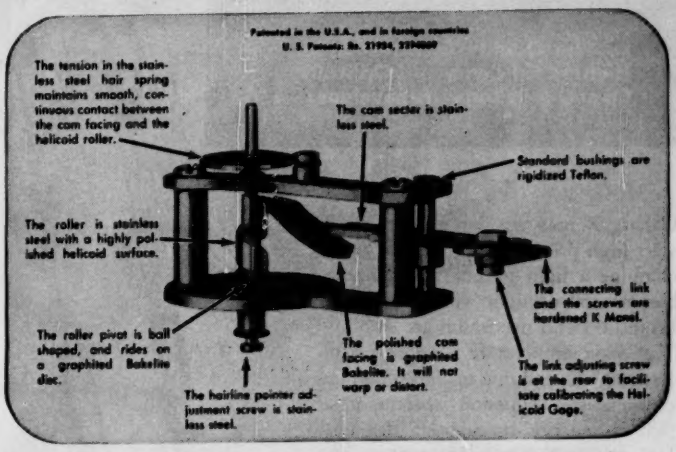
ALARM/CONTROL SYSTEM

New Alarm/Control System designed primarily for utilities, pipelines, railroads and similar companies which monitor and control unattended locations remotely from a central control point, can be used with various



types of transmission media, such as microwave, carrier current, or wire lines. They can check a single location or as many as 100 different points, with 10 functions at each point. The console has a bank of 10 indicator lamps to show the stations being selected and a second bank to show whether any faults are present. —*General Electric Co., Communication Products Dept., Lynchburg, Virginia.*

CIRCLE 243 ON READER-SERVICE CARD


Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21994, 2294809
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details **Ask for Catalog DH-65**

HELICOID GAGES

Helicoid Gage Division • American Chain & Cable Company, Inc.

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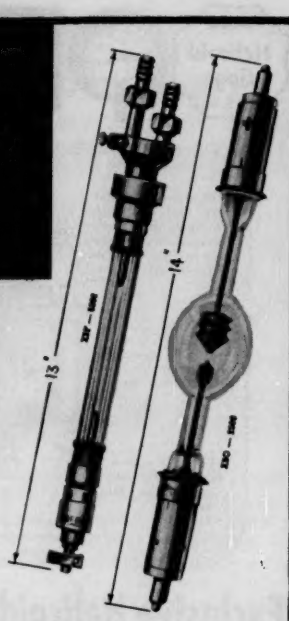
CIRCLE 122 ON READER-SERVICE CARD

OSRAM XENON
GASEOUS DISCHARGE LAMPS

Feature Quality Construction — Highest Efficiency — Optically Clear Quartz Long Life Envelopes.



Osram Xenon arc lamps are steady state-high pressure light sources which combine a light output which resembles natural daylight with a very high brightness and maximum arc stability. The color temperature is approximately 6000° K. and due to the Xenon gas characteristic emission spectra it is rich in energy throughout the near UV, visible and near IR regions. The XBO lamps listed below require no forced air cooling, XBF lamps shown require water cooling.

LAMP TYPE	ARC SIZE (in inches)	ARC BRIGHTNESS (Candles per Sq. cm.)	LUMINOUS FLUX (Lumens)
SHORT ARCS			
XBO- 162 AC-DC			3,200
XBO- 501 DC	.047 x .094	30,000	13,500
XBO-1001 DC	.067 x .134	40,000	32,000
XBO-2001 DC	.079 x .158	65,000	70,000
LONG ARCS			
XBF-6000 AC	4-5/16	3,000	215,000
XBF-6001 DC	4-5/16	4,500	205,000

RECOMMENDED USES:

- As a point source for optical systems and for microscope illumination.
- For beacons, spotlighting and backlighting.
- Illumination over a large area when used with properly designed reflectors.
- The illumination of slit monochromators and repeat type printers.
- Fade testing of materials.
- For technical and biological studies which require a close simulation of daylight.

Manufactured in West Germany.

For prices, more complete detail, the cost of auxiliary equipment, O.E.M. prices and quantity discounts, please address correspondence to:

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P.O. Box 950 Newburgh, N. Y.

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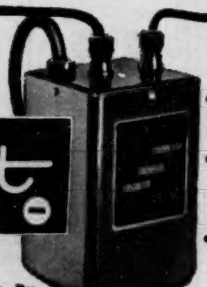
CIRCLE 123 ON READER-SERVICE CARD

INSTRULAB'S NEW

evenvolt

⊕ Constant Voltage Unit ⊖



REPLACES BATTERIES IN POTENTIOMETERS

- CONTROLLERS
- INDICATORS
- RECORDERS

Mfg. By INSTRULAB, INC.

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Dayton 4, Ohio
Phone BA 3-2241

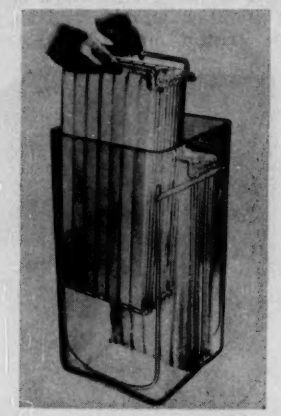
Outstanding FEATURES

- Eliminates batteries ...errors due to battery exhaustion
- Reliable construction... from quality components, long, trouble-free service
- A Precise voltage regulator . . . max, ±.04% for ±20% voltage variation
- Quickly Installed... Fits present instrument battery space.
- No Tubes to replace

CIRCLE 124 ON READER-SERVICE CARD

PAPER CHROMATOGRAPH

New apparatus allows a very large numbers of paper strips to be chromatographed at one time in a small

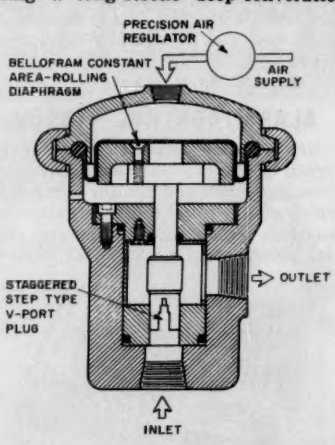


space and under identical conditions of solvent humidity, thus eliminating troublesome variables. Offered for both descending and ascending chromatographic separations.—*California Laboratory Equipment Co., 1717 Fifth St., Berkeley 10, Calif.*

CIRCLE 244 ON READER-SERVICE CARD

BACK-PRESSURE CONTROLLERS

New Micro Delta P Controller is a combined pressure sensing element, control pilot, and control valve utilizing a force-balance control system, giving very high response speed. Utilizing a long-stroke deep-convolution

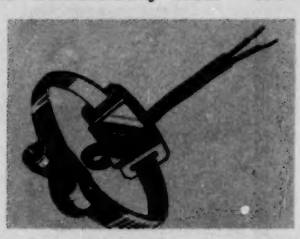


diaphragm seal, it furnishes accurate, stable, back-pressure control. Series-400 controllers, (and the smaller 1100-Series) provide pressure control up to 18:1 ratios. Repetitive control with an accuracy of ½ to 1% of full scale is possible through the inherent low hysteresis characteristics of this seal and its minimum spring gradient. Seal used in 1100-Series has a 3" bore dia, while the 400-Series seal is 7" in dia.—*Industrial Engineering Corp., 525 E. Woodbine, Louisville 8, Ky.*

CIRCLE 245 ON READER-SERVICE CARD

SURFACE THERMOMETERS

New RdF Strapon self-contained Surface Thermometers operate at temperatures from −100° to +500°F (and intermittently from −300° to



+575°F), and consist of a 100-ohm (at 70°F) CP nickel element completely encapsulated in silicone rubber and stainless steel (0.002" thick to provide maximum flexibility). Can be immersed in fluids, molded into units where inside temperature is to be measured, or strapped to the outside of a pipe to make measurements without shutting down a process.—*Arthur C. Ruge Associates, Inc., Hudson, N. H.*

CIRCLE 246 ON READER-SERVICE CARD

CT MATCHING UNIT

New modular CT Matching Unit is a capacity device for the most efficient energy transfer, to be connected between a high-frequency generator and a low-impedance work coil. Each section of the unit is rated at 100 kva in the frequency range of 100-750 Kcps. Available in 1, 2, 4, 6, and 8 sections, rated at 100, 200, 400, 600, and 800 kva respectively. Combinations of parallel and series connections between the individual sections provide several ranges of impedance, permitting efficient matching to even the smallest induction heating coils.—*Lepel High Frequency Labs., 55th St. and 37th Ave., Woodside, L. I., N. Y.*

CIRCLE 247 ON READER-SERVICE CARD

ELECTRONIC FRAMING CAMERA

New portable High Speed Framing Camera, Model 1, featuring box camera simplicity, uses special image-converter-type tube shutters with a speed range of 0.1 to 10 μsec. A separate shutter tube and objective lens are used for each exposure. Focus and aperture adjustments are completely independent for each channel. Each of the 4 channels has an independent time delay adjustable from 1 to 1000 μsec. Equipped with 4 f 1.4 Nikkor 50-mm objective lens, it uses a Wollensak 75-mm, f 1.9 recording lens.—*Abtronics, Inc., Livermore, Calif.*

CIRCLE 248 ON READER-SERVICE CARD

FOR MORE INFORMATION ON PRODUCTS REPORTED OR ADVERTISED IN THIS ISSUE, USE READER-SERVICE CARD ON PAGE 335.

HEISE GAUGES

IN RANGES UP TO

50,000 psi.

The Heise Gauge, for many years a world standard for precision pressure measurement, is NOW available for use in ranges up to 50,000 psi.

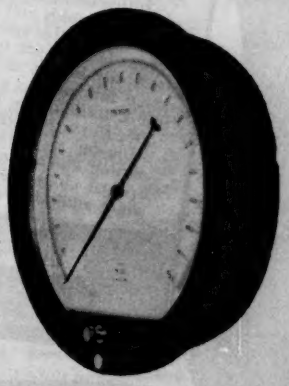
Control of this extreme pressure is made possible by the new Heise heavy duty Bourdon Tube, a single unit which eliminates all internal connections.

The Tube, made from #403 Stainless Steel, is multi-coiled to reduce unit stress and formed to a scientifically precise section by an exclusive Heise process.

Mounted on the Heise integral gauge movement this unique element initiates a new concept in pressure gauge design.

The 50,000 lb. gauge features the traditional high quality workmanship expected of all Heise equipment.

Accuracy is held to 1/10 of 1% of full scale reading in this ultra high pressure laboratory instrument.



PRESSURE RANGES	DIAL SIZES	PRICES	DELIVERY
15 to 50,000 P.S.I.	8½"-12"-16"	from $166.75	within 30 days

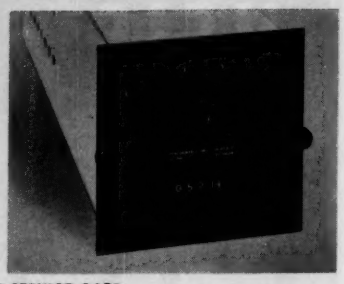
HEISE BOURDON TUBE COMPANY, INC.

BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 125 ON READER-SERVICE CARD

DIGITAL TORQUE INDICATOR

New Digital Torque Indicator, Model 756TA, that integrates torque fluctuations from equipment on thrust, weight, pressure, temperature, and flow tests, contains a special compact filter network to produce true, averaged readout by integrating all torque fluctuations above 3 cps. Indicator accuracy is ±0.1%.—*Performance Measurements Co.*, 15301 *W. McNichols Rd., Detroit* 35, *Mich.*



CIRCLE 249 ON READER-SERVICE CARD

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ARCCO ANUBIS
LIQUID GRAVITOMETER
FOR PIPELINES, REFINERIES, GASOLINE PLANTS
NOW
19 MODELS
MODEL R
Wherever the specific gravity of liquid products or processing fluids is an important factor Arcco-Anubis Liquid Gravitometers will render accurate recordings of continuous flow and spot checks of samples under varying conditions of temperature and pressure. Foreign liquids and gases are automatically purged. Changes in the specific gravity of the sample are recorded almost instantly. High pressure and high viscosity liquids are handled with ease. Charts graduated for specific gravity are available in over 100 ranges. Charts for Degrees A.P.I. are available in over 30 different ranges. Arcco Liquid Gravitometers are made for recording, controlling, indicating, transmitting and various combinations of these functions. Special charts when required can be furnished at slight additional cost.
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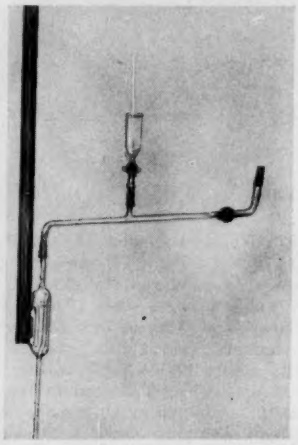
AMERICAN
RECORDING CHART COMPANY
7142 East Condor Street, Los Angeles 22, California
Send for Bulletin No. 111-R3
Send For Bulletin No. 111-R3

CIRCLE 126 ON READER-SERVICE CARD

VAPOR-PRESS THERMOMETER

New portable Vapor Pressure Thermometer that is filled with manometric fluid and calibrating gas, is



an entirely separate piece of apparatus. The probe extending from the bottom of the thermometer can be modified so as to be immersed in any cryogenic system. Bulletin 10 gives details.—*Delmar Scientific Labs.*, 4701 *West Grand Ave., Chicago* 39, *Ill.*

CIRCLE 250 ON READER-SERVICE CARD

NOISE INTEGRATOR

New Noise Integrator provides either integrated or average noise level readings in areas of rapidly fluctuating sound. Used in conjunction with the M-S-A Noise Survey Meter it collects the noise-generated signal for 5 sec, during which time

the meter reading increases to a point which is proportional to the integrated sound. A weighted frequency response signal is fed into the Integrator from the Survey Meter, which serves as microphone pick-up and preamplifier. The sum of the survey meter attentuator setting plus the integrator reading provides a time-vs-total-noise value, and is expressed in "dose" units.—*Mine Safety Appliances Co.*, 201 *N. Braddock St., Pittsburgh* 8, *Pa.*

CIRCLE 251 ON READER-SERVICE CARD

PORTABLE PYROMETER

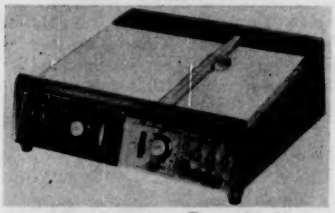
New Portable Indicating Pyrometer, Alnor Type 2300-B, has two scales or arcs in order to provide 1°F per scale division and readability

to at least the nearest ½°F. Ranges are −40°F to + 200°F. A selection of interchangeable thermocouples is available. Bulletin 2146-C contains details.—*Illinois Testing Laboratories, Inc., 420 North LaSalle St., Chicago 10, Ill.*

CIRCLE 252 ON READER-SERVICE CARD

X-Y RECORDER

New Autograf Recorder, Model 2D, a precision x-y Recorder with intgral ac/dc input and a built-in x-axis time base, operates directly from a transducer and eliminates the need for an

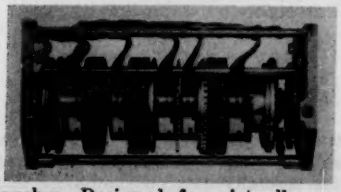


extra a-c converter. D-c ranges provide accuracy and resolution of better than 0.2%. Input range is 7.5 mv to 150 v on the x-axis; 5 mv to 100 v on the y-axis. The x-axis time base (5 steps) is 7.5 to 750 sec. Input resistance is 200,000 ohms/v.—*F. L. Moseley Co., 409 N. Fair Oaks Ave., Pasadena, Calif.*

CIRCLE 253 ON READER-SERVICE CARD

VADAC UNIT

New Time Index Indicator Digitalizer; a direct reading analog-to-digital Converter displays time values in hours, min, and sec; and transmit this information simultaneuosly as a coded electrical signal by means of coded drum assemblies and pick-off



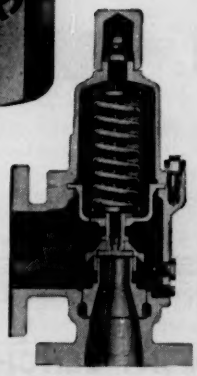
brushes. Designed for virtually any mode of binary expression from simple pure binary (scaler) to cyclic binary, binary decimal, or cyclic binary decimal.—*Kearfott Div. of General Precision, Inc., 1500 Main Ave., Clifton, N. J.*

CIRCLE 254 ON READER-SERVICE CAD

in process safety-relief valves

From the Near East to our own Far West . . . the name Farris on safety-relief valves has been a standard synonym for safety since 1943. The patented design features on all Farris full-nozzle valves combine to offer the ideal concept of a trouble-free, 100% safe safety-relief valve for every application.

2745



2950

SERIES 2600

The most popular top-guided, self-aligning, safety-relief valve for process piping service. Maximum pressure, 150 to 2500 psig, RF/RJ. Plain or Lever types. Standard or BalanSeal bellows construction.

SERIES 2740

A cast-steel relief valve of simplified design for use where extreme blow down accuracy is not essential, but where durability, compactness are. Pressures to 3500 psig at 450°F; 2000 psig at 800°F. Sizes ½" to 2".

SERIES 2745

An extremely rugged, compact, high pressure bar stock nozzle valve. Internal parts stainless steel. Adjustable blow down; flat seat; self-aligning stem and disc. Pressure to 10,000 psig. Sizes ½", ¾", 1".

SERIES 2950

A cast iron safety-relief valve including most of the exclusive Farris features found in the Series 2600. Max. pressure, 250 psig at 450°F, 400 psig at 150°F. Plain cap, open lever or packed lever types.

Complete information is provided in Catalog FE-118, covering both selection and sizing of Farris process Safety-Relief Valves. Send for your copy today.

Farris ENGINEERING CORP.

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CIRCLE 127 ON READER-SERVICE CARD

OUR TWENTY-FIFTH ANNIVERSARY

NEW! GOW-MAC

Gas Density Detector

- NO CALIBRATION REQUIRED
- LINEAR ACROSS BROAD RANGES OF CONCENTRATION
- REQUIRES NO SCARCE OR COSTLY CARRIER GASES

Now a practical reality for 1960! Researchers at Standard Oil Company (Indiana) have designed a simple density detector that fulfills all these requirements. In cooperation with them, GOW-MAC has produced a commercial prototype.

The Gas Density Detector is the only one in use today that measures a single additive physical property of the chromatography gas, i.e., a property that depends only upon the number and kind of atoms in the molecule. Knowing the molecular weight of the components, the chromatographic peak areas can be converted directly into weight per cent. If the molecular weights are unknown, they can be determined by the Gas Density Detector. Measurements made by the Gas Density Detector are closely comparable to those from thermal conductivity cells. Precision and accuracy are excellent.

SEE DECEMBER ISSUE, ANALYTICAL CHEMISTRY—
"The composition of Crude Oil through Seven Carbons as Determined by Gas Chromatography" by Martin and Winters.

ON DISPLAY AT THE PITTSBURGH CONFERENCE,
Feb. 29 to March 4, BOOTH 406

Write for full information; address inquiries to Department IA

GOW-MAC INSTRUMENT COMPANY
100 KINGS ROAD, MADISON, NEW JERSEY, U. S. A.
Telephone FRontier 7-3450

1935-1960 OUR TWENTY-FIFTH ANNIVERSARY

CIRCLE 128 ON READER-SERVICE CARD

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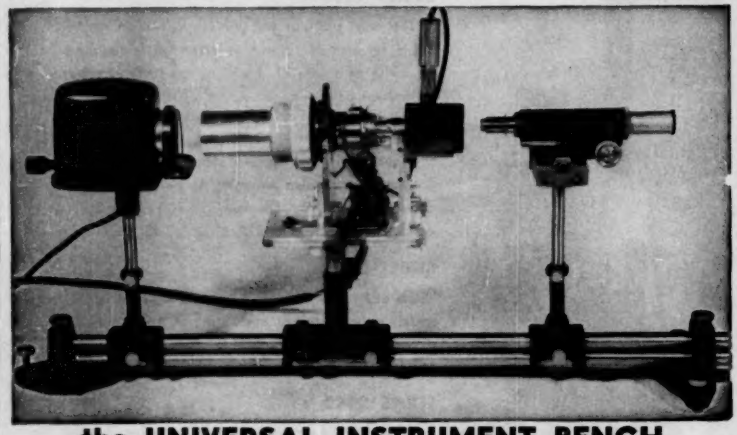

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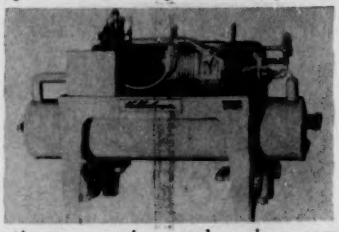
CIRCLE 129 ON READER-SERVICE CARD

INSTRUMENT AIR DRYER

New KCD Air Dryer is based on the principle of sub-dewpoint refrigeration condensing water and oil vapors from compressed air, elimi-

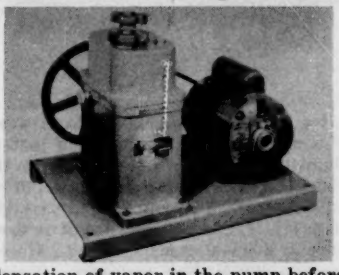


nating expensive carbon-ring compressors and special desiccants. Features include a semi-hermetic type motor compressor; R-12 refrigerant-cooled heat exchangers; and controls consisting of an air temperature control thermostat, an outlet air thermometer, a safety switch, thermo expansion valve, and automatic water regulating valve.—*Kohlenberger Engineering Corp., 1600 W. Commonwealth Ave., Fullerton, Calif.*

CIRCLE 255 ON READER-SERVICE CARD

VACUUM PUMPS

New Leybold Rotary Gas Ballast Vaccum Pumps (manufactured in West Germany) are equipped with a gas ballast device that prevents con-



densation of vapor in the pump before it can occur. Models available include single-stage pumps (attaining an ultimate vacuum of 2×10^{-3} mm of Mg) and pumps with two stages in series, attaining an ultimate vacuum of 2×10^{-5} mm Hg. Both are available in two sizes: (1) with a speed of 33 lit/min; (2) with a speed of 100 lit/min.—*Arthur S. LaPine and Co., 6001 South Knox Ave., Chicago 29, Ill.*

CIRCLE 256 ON READER-SERVICE CARD

PEAK ACCELEROMETER

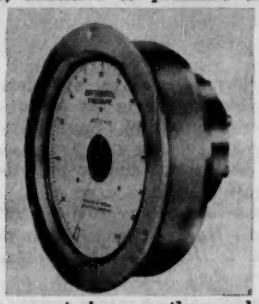
New Peak Accelerometer which accurately measures true peak-G in shock and vibration tests, contains a barium titnate transducer connected to a specially designed amplifier and indicator unit which retains the peak reading for 15 sec for shock measurements, or follows the peak acceleration reading when the instrument is set to make vibration measurements. Four ranges are provided for accelerations up to 1000 G which are indicated on a 3½" meter with a mirror

scale and a knife-edge pointer.—*Ferranti Electric, Inc., Electronics Div., 95 Madison Ave., Hempstead, L. I., N. Y.*

CIRCLE 257 ON READER-SERVICE CARD

DIFFERENTIAL GAGE

New Hi Line Pressure-Lo Differential Gage, Series FA-236, is suitable for either gas or liquid service. It is accurate to 0.5% of full scale range, sensitive to pressure change

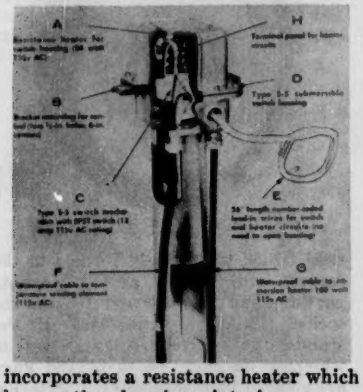


of one part in one thousand, and fully temperature compensated. The mechanism contains no pressure transfer liquid subject to contamination. —*Wallace & Tiernan Inc., Belleville 9, N. J.*

CIRCLE 258 ON READER-SERVICE CARD

LIQUID LEVEL CONTROLLER

New No-Freeze Liquid Level Controller, Model A-101, can be installed in outdoor water storage tanks as it



incorporates a resistance heater which keeps the housing interior warm. Thus the displacers always monitor the true level of tank water. Displacers are set to maintain a constant 36" differential.—*Magnetrol, Inc., 2110 South Marshall Blvd., Chicago 23, Ill.*

CIRCLE 259 ON READER-SERVICE CARD

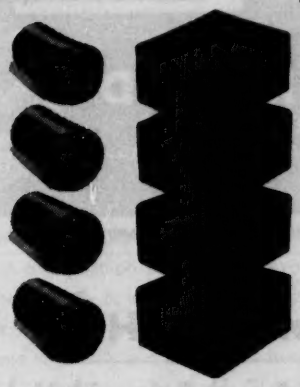
BH100 Series

MILLI-V-METER®

The instrument with the TAPE-SLIDEWIRE

for Test Cells
Ground Support
Flight Deck
Telemetry

...to accurately indicate



TEMPERATURE
R.P.M.
PRESSURE
FLOW

1/10 THE SIZE, 10 TIMES THE ACCURACY
(of standard instruments)!

These 3x5" and 3"-dia. instruments are used by many manufacturers and laboratories to measure every parameter... in missile, aircraft or ground support. Ideally small and matched for panel uniformity, they offer reading of the individual phenomenon or of many states through selector switching... with fast response. Every measurement exhibited on the counter is a definitely calibrated value. Component density of the 3"-dia. BH183 is the highest obtainable combined with ultimate instrument accuracy. Manufactured to MIL-E-5272 and MIL-I-6181 specs.

FEATURES:

1) Accuracy 1 part in 1000.
2) Laboratory precision for the military or industry.
3) Compatibility with any transducer —AC or DC.
4) For strain gage, linear differential transformer, thermocouple, thermistor, resistance thermometer, pulse or variable frequency circuits or systems.
5) Available with re-transmitting slidewire.
6) Every scale unit a calibrated value.
7) Operates directly from 60- or 400-cycle power.

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CIRCLE 130 ON READER-SERVICE CARD

NEW...
VIBRATING
CAPACITOR
A vibrating-reed type capacitance modulator for use in measuring currents as low as 10^{-16} amperes.
Long term stability for process control. Drift ±0.2 millivolts per day, non-cum.
Write for Catalog 523.
STEVENS-ARNOLD
INCORPORATED
7 ELKINS STREET, SOUTH BOSTON 27, MASS.

CIRCLE 131 ON READER-SERVICE CARD

New...from MARSH!

Conduit-type Master-mite. Grommet-type also available.

Small Solenoid Valves that fill a BIG Order

Designed to meet the need for positive-acting tight-seating valves for use on wide variety of media, including oxygen, hydrogen, acetylene, etc.

Two Types:
Conduit type and grommet type. Port sizes 1/8" and 1/4" NPT.

Ten orifice sizes: 3/64" through 1/4".

Wide range of voltages:
Standard with 115 V. A. C. but also available in 12, 24, 208, 230, 460 V. A. C.

Pressure to 540 psi.
Small, but with more strength in the Marsh manner. Coils never overheat. Entire assembly leak tight. Remarkably quiet operation. Cleanable without breaking connections. Used in any position. Bodies either brass bar stock or 18-8 stainless steel. All moving parts stainless. Underwriters' approved for use on oxygen and hydrogen and as safety valves.

Write for new bulletin

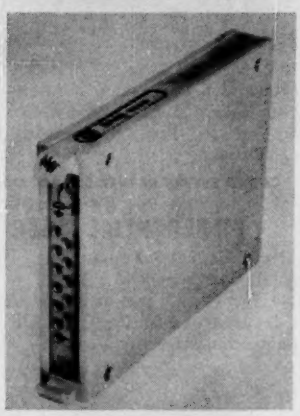
MARSH INSTRUMENT COMPANY
Dept. 42, Skokie, Illinois
Division of Colorado Oil and Gas Corporation
Marsh Instrument & Valve Co., (Canada) Ltd., 8407 103rd St., Edmonton, Alberta, Canada, Houston Branch Plant, 1121 Rothwell St., Sect. 15, Houston, Texas.

CIRCLE 132 ON READER-SERVICE CARD

NEW INSTRUMENTS

DELAY B UNIT

New Delay B Unit for sensing memory plains, changing logical timing in a system and other uses where

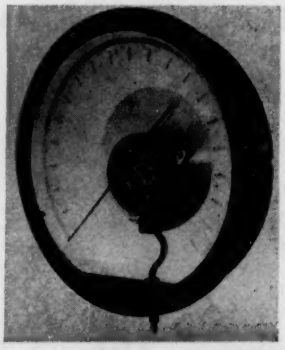


short pulse delays are desired, is capable of driving the bases of three other transistors. Specifications include: negative 4-v, 1/10-μsec pulse for both input and output; delay increments at 0.03 μsec each; and up to 0.3-μsec delay provided by the 10 taps.—*Harvey-Wells Electronics, Inc., R & D Div., East Natick Industrial Park, East Natick, Mass.*

CIRCLE 260 ON READER-SERVICE CARD

TEST GAGES

New 8½"-12"-16" Test Gages with 50,000-psig range and accuracy of 1/10 of 1% of full scale incorporate a one-piece helical tube of stainless

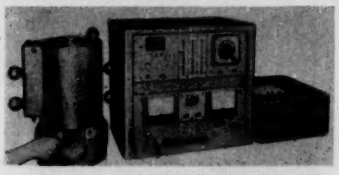


steel which is precisely formed to the correct oval section at the working portion, and rigidly mounted on the socket casting to the base of the standard integral movement, a unit in which all moving parts of the gage are related and isolated from external forces. A bimetal-bar thermal compensator makes possible continuous pressure readings through a temperature change of 100°F without manual resetting or thermal error computation.—*Heise Bourbon Tube Co., 1 Brook Rd., Newtown, Conn.*

CIRCLE 261 ON READER-SERVICE CARD

GAMMA SPECTROMETER SYSTEM

New Gamma Spectrometer System, Model GSS-1, offers excellent resolution and great precision employing photomultiplier tubes, transistors, and sensitive discriminators. The pulse is

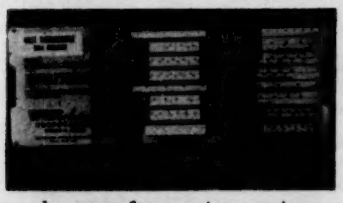


brought to the window rather than the window to the pulse. Built around two basic components, a combination linear-count ratemeter and all-transistorized spectrometer circuit, and a probe assembly including spectrometer grade photomultiplier tube with 2" x 2" NaI scintillation crystal, coupled directly to an all-transistorized amplifier. A universal shield with sample slides, a decade type slave scaler, and a graphic recorder are integrated with the system.—*Nuclear Measurements Corp.*, 2460 *N. Arlington Ave., Indianapolis* 18, *Ind.*

CIRCLE 262 ON READER-SERVICE CARD

THERMOCOUPLE CALCULATOR

New Thermocouple Data Indicator gives mv values for Fe/Constantan, Cu/Constantan, Chromel/Alumel, Pt-13% Rh/Pt and Pt-10% Rh/Pt thermocouples. Readings are based on a

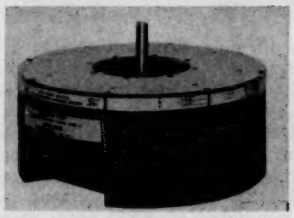


zero-degree reference temperature or corrected to any ambient temperature.—*West Instrument Corp.*, 4363 *West Montrose Ave., Chicago* 41, *Ill.*

CIRCLE 263 ON READER-SERVICE CARD

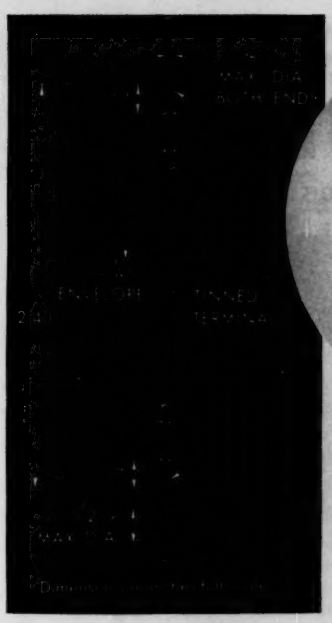
SHAFT POSITION ENCODER

New Type RD-17 Digisyn is a highly precise Photoelectric Shaft-Position Encoder giving unambiguous



angular position data in 17-digit cyclic binary code with ± one-digit accuracy (± 10 sec of arc).—*Wayne-George Corp.*, 588 *Commonwealth Ave., Boston* 15, *Mass.*

CIRCLE 264 ON READER-SERVICE CARD



the mighty little glaswitch*

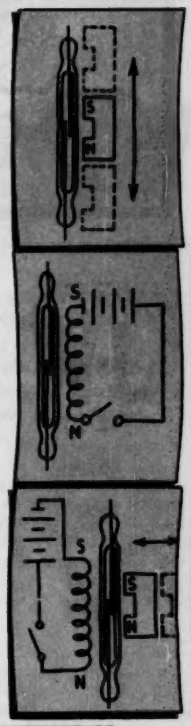
LIGHTNING RESPONSE . . . SEALED IN GLASS

The magnetically actuated reeds in this tiny Revere GLASWITCH make contact in just 1 millisecond . . . at rates up to 400 cycles per second. Hermetically sealed in an inert, dry atmosphere, with lightning fast snap action, both shelf and contact life are extremely long. Smaller than a cigarette, the GLASWITCH can be located anywhere . . . in any position . . . even in explosive atmospheres . . . individually or in multiples for multi-contact use.

Whenever you need faster, more positive response . . . where extreme sensitivity is a must . . . where light weight is important . . . investigate the Revere GLASWITCH. Write today for complete specifications.

CHARACTERISTICS:

Type—Single pole single throw—normally open—snap action
Enclosure—Hermetically sealed glass tube containing inert dry atmosphere
Operating Time—1 millisecond
Operating Rate—Up to 400 cycles per second
Contact Surfaces—Electroplated Rhodium
Contact Resistance (measured terminal-to-terminal)
Closed Circuit—0.050 ohms maximum
Open Circuit—500,000 megohms minimum
Contact Ratings
DC—Up to 1 ampere
AC—Up to 25 watts depending on application
Reliability and Life
No Load—Billions of operations
Rated Loads—No failures to open or close in first 100,000 cycles
Ambient Temperature Range: —320°F to +300°F



METHODS OF ACTUATION:

A moving permanent magnet or controlled external electromagnetic field are all you need . . . and the sky's the limit on imagination!

1R

REVERE CORPORATION OF AMERICA

Wallingford, Connecticut

A SUBSIDIARY OF NEPTUNE METER COMPANY

CIRCLE 133 ON READER-SERVICE CARD

PYRAMID "INSTRUPACK"

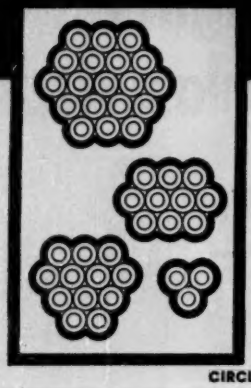
(TUBING BUNDLES)

POLYETHYLENE TUBES ENCLOSED IN VIRGIN PVC (VINYL) SHEATH

STANDARD

Tubing—¼" O.D. x .040" Wall, .045" or .062" Sheath

Tubing—⅜" O.D. x .062" Wall, .045" or .062" Sheath



Tough vinyl outer sheath with excellent chemical atmospheric resistance. Inside tubes are Polyethylene available in standard colors with pair of telephone wire leads. Lengths to requirements.

STOCK POLYETHYLENE TUBING—¼" O.D. x .040" wall and ⅜" O.D. x .062" wall, in standard colors.

PLASTIC COATED METAL TUBING—standards and specials to order.

Write for Bulletin PPI-59.

PYRAMID PLASTICS, INC.

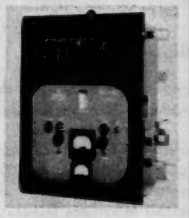
556 W. Polk St., Chicago 7, Ill.

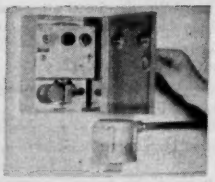
CIRCLE 134 ON READER-SERVICE CARD

J-W Systems for Continuous Checking for Explosive Gases

J-W Model RV Alarms sample and analyze air at 2 to 8 locations and relay information to main analyzer panel. Recording instruments and explosion-proof construction available on order.

J-W Model SM Alarm continuously checks one location where accessibility is a problem; alarms at a pre-set level.





J-W Model E Alarm detects explosive gases in a single area; control box mounts remote from sensing unit. Model EE also available with units encased in explosion-proof housing.

Do you have a problem with combustible gases that requires a special detection system design? Experienced J-W engineering is available to help you with meeting the situation. For complete data on services and standard and custom J-W equipment, please write:

JOHNSON-WILLIAMS, INC. Palo Alto 13, California

Leaders in Explosion Prevention Since 1927

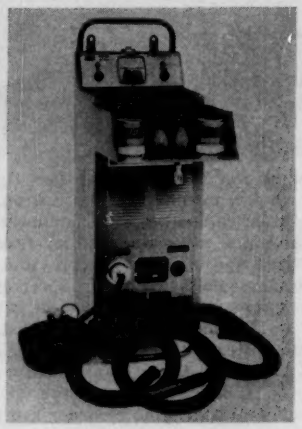
Canadian customers please write: SAFETY SUPPLY CO. TORONTO, ONT. FLECK BROS. LTD. VANCOUVER, B. C.

CIRCLE 135 ON READER-SERVICE CARD

NEW INSTRUMENTS

FLAW DETECTOR

New light-weight, portable, magnetic particle Inspection Machine, Model AH-7, used to find cracks or

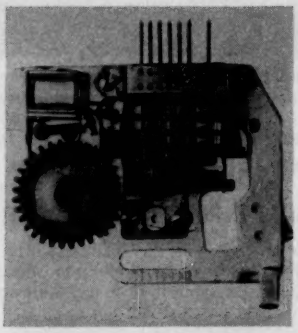


flaws in welds and castings and for maintenance inspection on all types of metal, operates on 115 vac, and has both a-c and half-wave d-c outputs. Made to MIL-M-19698A.—*Sonoflux Div. of Peterson Machine Tool, Inc., 6200 Merriam Dr., Merriam, Kansas.*

CIRCLE 265 ON READER-SERVICE CARD

LOGIC SWITCHES

New line of electromechanical Logic Switches and Decimal Counters for data handling systems and computers, reduces to ½ the pulse times necessary to resolve systems logic. Fea-

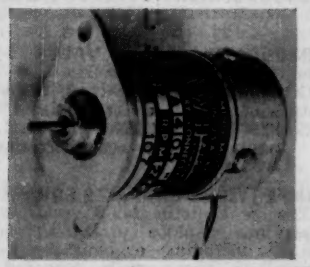


tures include fixed state stability, short term switching response delay, multiple set contact arrays, repeatable operate and drop-out times, and complete separation of switching elements. Three basic elements are combined in each switch: (1) a delay element, (2) a bi-stable element, and (3) a number of AND gates associated either with the assert or negative side of the bi-stable element. Bulletin TRC-LC-2 contains details.—*Tally Register Corp., 5300 14th Ave., N. W., Seattle 7, Wash.*

CIRCLE 266 ON READER-SERVICE CARD

SUB-MIN D-C MOTORS

New line of sub-miniature, reversible D-C Motors, Series 14100, features extreme compactness, high torque, low rotor inertia (5gm-cm²),



and high efficiency. Measuring less than 1" dia, 1⅜" long, and weighing only two ounces, a motor of this type was used to drive a miniature tape recorder in the Vanguard 11 weather satellite which is expected to remain in orbit for 200 years. Speed tolerance of ±10% can be maintained at rated voltage.—*A. W. Haydon Co., 232 N. Elm St., Waterbury, Conn.*

CIRCLE 267 ON READER-SERVICE CARD

PRESET TOTALIZERS

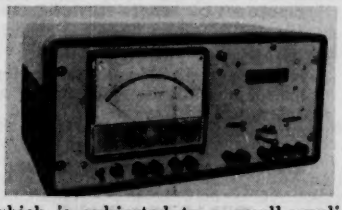
New Modular 500 Series of single or multiple Preset Totalizers; for packaging, multiple-lap coil winding,

length cutting, and periodic thickness measurement; provides absolute accuracies of 100,000 events/sec. Use of in-line thumb-wheel switches provides easy adjustment of desired or predetermined count totals.—*Iconix Inc., 945 Industrial Ave., Palo Alto, Calif.*

CIRCLE 268 ON READER-SERVICE CARD

ELECTRONIC WATTMETER

New Electronic Wattmeter, Model 1483, has a low-impedance d-c current output, thus can actuate digital meters; remote, indicating d-c milliammeters; and drive strip-chart recorders. Featuring a sensing element

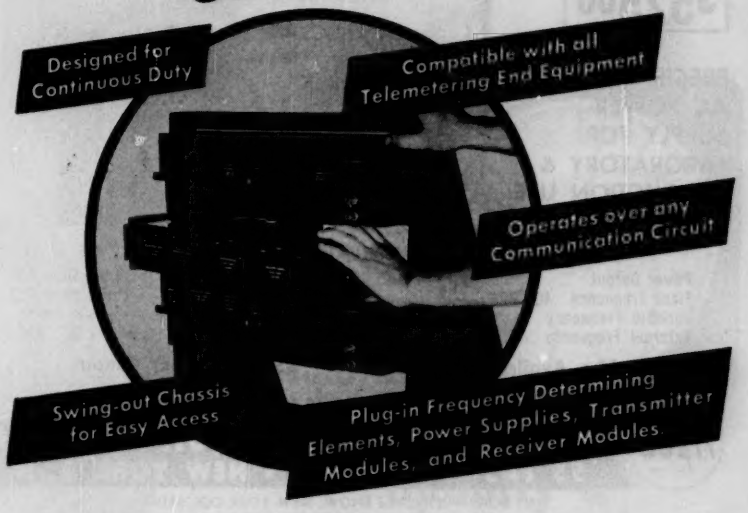


which is subjected to a small-amplitude vibration by a 200-kc exciting field contained in its feedback system, static friction is eliminated, and resolution down to 0.01% of rated input is obtained.—*Daystrom-Weston Sales Div., Daystrom, Incorporated, 614 Freling-huysen Ave., Newark 12, N. J.*

CIRCLE 269 ON READER-SERVICE CARD

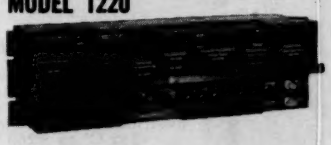
REMOTE INSTRUMENTATION & CONTROL

Comtel® Transistorized Modular Terminal Units for TELEMETERING and CONTROL APPLICATIONS


Designed for Continuous Duty
Compatible with all Telemetering End Equipment
Operates over any Communication Circuit
Swing-out Chassis for Easy Access
Plug-in Frequency Determining Elements, Power Supplies, Transmitter Modules, and Receiver Modules.

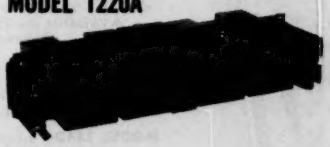
The Model 1220 and 1220A Carrier Terminals are completely transistorized and may be operated from station batteries from 12 to 130 DC. Plug-in power supply is available for 115-volt AC operation. All components, including amplifiers, frequency determining components, and power supplies are contained in plug-in modules, and may be readily interchanged. As many as 22 high-speed channels are available between 300 to 3000 cps.

MODEL 1220



The Model 1220 Terminals are normally used in telegraph applications and provide all necessary carrier and loop jack fields, as well as loop current controls. Two transmitters, two receivers, or a transmitter receiver are available on a single 5¼" x 19" chassis. Operates from station battery or 117-volt AC line.

MODEL 1220A



The Model 1220A Terminals are normally used in telemetering and control applications. The individual modules are mounted on a swing-out chassis and are readily accessible. Four transmitters, four receivers, or two transmitter receivers are available on a single 3½" x 19" chassis. Operates from station battery or 117-volt AC line.

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W. L. Cunningham, Elmhurst, Ill.

TEXAS, ARK., LA., OKLA.
Datatrol Co., Dallas, Texas

ALA., TENN., VA., N.C., S.C., GA.
Dickerson Eng., Jacksonville, Fla.

CALIFORNIA
Luscombe Engr., Pasadena, Calif.

ORE., WASH.
J. E. Edstrom, Portland, Ore.

CANADA
Microwave Sys., Scarborough, Ont.

FOREIGN
Telesco International, New York

SEND FOR TECH. DATA — For additional information, including application data, write or phone DE 4-3100. Demonstrations available by local representatives.

RFL Radio Frequency LABORATORIES, INC. Boonton, New Jersey, U.S.A.

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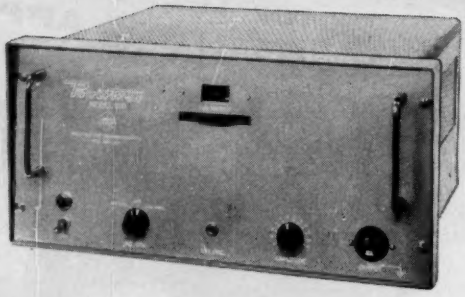
NEW Powertron

AC ELECTRONIC GENERATOR

MODEL 150
$525.00



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Power Output	160 V.A.	Total Distortion	Less than 1%
Fixed Frequency	400 CPS (other freq. avail.)	Regulation	Less than 1%
Variable Frequency	350-450 CPS	Operates with load of any power factor	
External Frequency	50-4000 CPS	Small size	8¾" x 19" Panel

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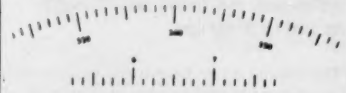

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Illustrated Models

MODEL 162A Working standard thermometer. Stability is 0.01 C° over most of range from -182 C° to +260 C° (other models to -265 C° on request). Available on fast delivery.

MODEL 150B Miniature liquid hydrogen probe. The diameter is only 0.160 inches.

MODEL 134D Liquid oxygen probe. Widely used for Missile applications. High stability.

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Minneapolis 24, Minn.

CIRCLE 139 ON READER-SERVICE CARD

ICS NEW LITERATURE

VALVES

REGULATING RELIEF VALVE. 2-page bulletin describes the No. 280 Type G regulating relief valve with photos, drawings and chart.—Atlas Valve Co., 280 South St., Newark, N. J.
CIRCLE 270 ON READER-SERVICE CARD

IMPERVIOUS GRAPHITE EQUIPMENT. 32-page Bulletin 249-2 describes impervious-graphite processing equipment including exchangers, valves, crucibles, thermowells, armored and non-armored types of pipe and fittings, immersion heaters, cascade coolers, and rupture discs; and gives data for cost estimation.—Falls Industries, Inc., Aurora Rd., Solon, Ohio.
CIRCLE 271 ON READER-SERVICE CARD

PRESSURE, VACUUM LOAD

DIFFERENTIAL PRESSURE GAGE. 2-page Data Sheet TP-47-A-1 contains features, technical, and design and operation data of Series FA-236 hi-pressure/lo-differential gage.—Wallace & Tiernan Inc., 25 Main St., Belleville 9, N. J.
CIRCLE 272 ON READER-SERVICE CARD

MULTI-POINTER GAGE UNIT. 4-page Product Specification M42-2 describes and illustrates multi-pointer gage units, used for pressure and level measurements, and pneumatic transmitting or receiving.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.
CIRCLE 273 ON READER-SERVICE CARD

SUB-MIN PRESSURE SWITCH. 2-page Bulletin AV2015 illustrates and describes Type C2060 switch, with operating characteristics.—Bristol Company, Aircraft Equipment Div., Waterbury 20, Conn.
CIRCLE 274 ON READER-SERVICE CARD

LOAD DETECTION DEVICES. 8-page booklet entitled "Ametron Electronic Scale Instrumentation" contains information on basic instrumentation and accessories for industrial processes.—Streeter-Amet Co., Grayslake, Ill.
CIRCLE 275 ON READER-SERVICE CARD

MECHANICAL VACUUM PUMPS. 16-page Booklet HY2A contains instructions for installation, operation, and maintenance of Hyvac 2, 7, and 14 pumps.—Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
CIRCLE 276 ON READER-SERVICE CARD

TEMPERATURE

INSULATED THERMOCOUPLES. 20-page Catalog 300 contains illustrations and descriptions of Con-O-Clad mineral-insulated thermocouples with method of manufacture.—Conax Corp., 2300 Walden Ave., Buffalo 25, N. Y.
CIRCLE 277 ON READER-SERVICE CARD

IGS NEW LITERATURE

OXIDE-INSULATED THERMOCOUPLES 4-page Catalog 101 illustrates and describes metallic-sheathed, hard-packed, oxide-insulated thermocouples and extension wire.—Research Instruments, Inc., 12410 Triskett Rd., Cleveland 11, Ohio.
CIRCLE 278 ON READER-SERVICE CARD

INDUSTRIAL THERMOMETERS. 4-page bulletin describes and illustrates industrial thermometers in air duct and moisture-proof models.—Precision Thermometer & Instrument Co., 1434 Brandywine St., Phila. 30, Pa.
CIRCLE 279 ON READER-SERVICE CARD

PYROMETER CONTROLLER. 4-page Bulletin 0035 contains information on principle of operation and applications of Type Z5 indicating pyrometer controller.—Atlantic Pyrometers, Inc., 190 Warburton Ave., Hawthorne, N. J.
CIRCLE 280 ON READER-SERVICE CARD

TEMPERATURE PROBE. 2-page Bulletin 8 contains dimensional sketch, principle of operation, and specs of high-gas-temperature probe T-1006-6.—Aero Research Instrument Co., Inc., 315 North Aberdeen St., Chicago 7, Ill.
CIRCLE 281 ON READER-SERVICE CARD

TIME, SPEED

PROCESS TIMERS. 4-page Bulletin GEZ-2985, describes Type TSA-14 adjustable "on" time units.—General Electric Co., Schenectady 5, N. Y.
CIRCLE 282 ON READER-SERVICE CARD

ELECTRONIC TACHOMETER. 2-page Bulletin F-53 describes TACH-PAK, a completely self-contained tachometer with an accuracy of better than 0.25%.—Airpax Electronics Inc., Seminole Div., Fort Lauderdale, Fla.
CIRCLE 283 ON READER-SERVICE CARD

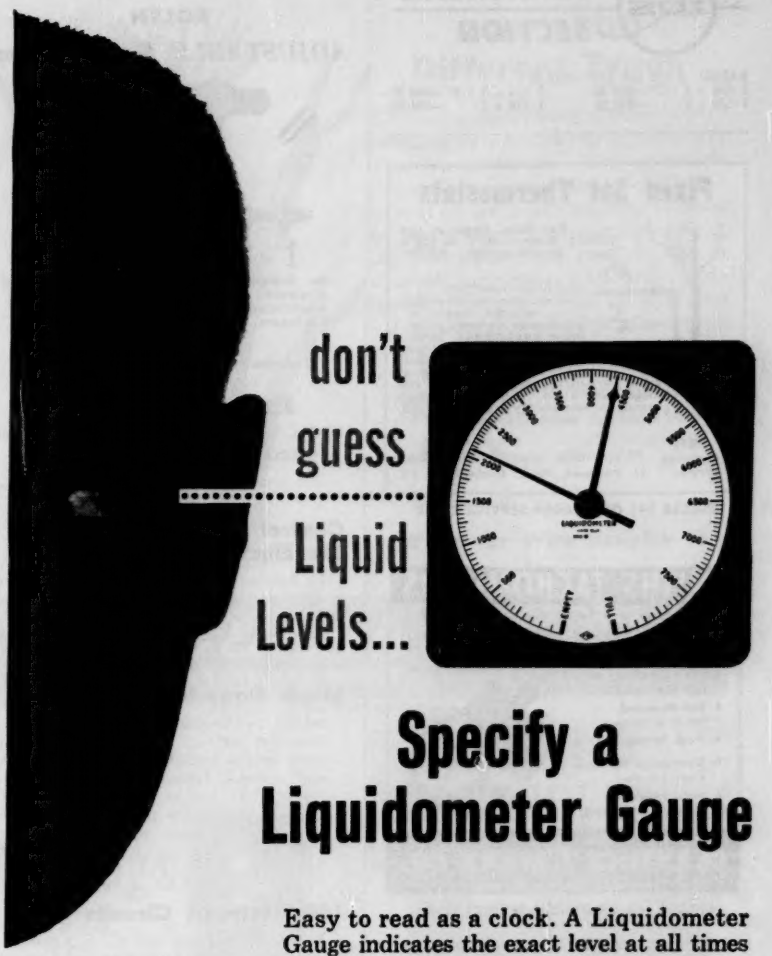
AIR VELOCITY METERS. 4-page Catalog 170 describes the various models of air-meters operating on a patented compensated heated thermopile principle.—Hastings-Raydist, Inc., Hampton, Virginia.
CIRCLE 284 ON READER-SERVICE CARD

AIR

DEHYDRATORS. 2-page Bulletin 103 discusses two new Dehydafilter units, Models CM-4-06 and CM-6-1.—Hankison Corp., College & Pike, Canonsburg, Penna.
CIRCLE 285 ON READER-SERVICE CARD

AIR DRYER. 12-page folder contains general descriptions of operation, technical data, product applications, etc. of Dynadryer automatic air and gas dryer.—United States Dynamics Corp., Industrial Equipment Div., 1250 Columbus Ave., Boston 20, Mass.
CIRCLE 286 ON READER-SERVICE CARD

ELECTRONIC AIR CLEANER. 12-page Bulletin 405 contains complete information on hi-velocity electronic air cleaner.—Dollinger Corp., 11 Centre Park, Rochester 3, N. Y.
CIRCLE 287 ON READER-SERVICE CARD



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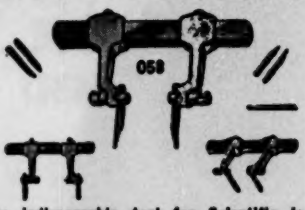

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CIRCLE 145 ON READER-SERVICE CARD

Control Handbook The Electronic

by Batcher and Moulic . . . presents electrical and electronic principles applicable to measurement and automatic control. Paper, 244 pages, illustrated, 1946. **$2.00**

Strain Gage Instrumentation

edited by Aronson and Nelson, ". . . a practical text . . . covers fundamentals, basic bridge circuits, typical applications, and surveys typical commercial instruments which use or are used with strain gages." Paper, 110 pages, illustrated indexed by company, author, and subject, 1958. **$2.00**

100 Electronic Circuits

by M. H. Aronson and C. F. Kezer . . . covers amplifiers, oscillators, pulse circuits, phase shifters, etc. Complete with all circuit component values and response specifications. Paper, 180 pages, 1957. **$2.00**

Automatic Control Technology

—Modern Theory and Their Usefulness. Includes 90 advanced papers on control technology as delivered in original language (about ½ of book is in English). Cloth, 9 x 12", 508 pages, 1957. **$25.00**

Digital Techniques for Computation and Control

by Klein, Morgan and Aronson . . . all basic digital techniques within one text . . . code arithmetic, logical networks, multiplexing, conversion, data reduction, digital process control, two-terminal relay circuits, counting techniques, digital computers, programming, digital differential analyzers, and combined analog-digital equipments. Cloth, 394 pages, illustrated, 1958. **$6.00**

Instruments Publishing Co.
845 Ridge Avenue
Pittsburgh 12, Pa.

RECORDERS

RECORDING OSCILLOGRAPH. 16-page Bulletin 1500 describes the 18- or 26-channel Type 5-114 recording oscillograph.—Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 288 ON READER-SERVICE CARD

OPTICAL X-Y RECORDER. 2-page bulletin describes the Model 670 optical x-y recorder with immediate readout. —Sanborn Co., Industrial Div., 175 Wyman St., Waltham 54, Mass.

CIRCLE 289 ON READER-SERVICE CARD

DATA HANDLING

ANALOG COMPUTERS. 4-page brochure describes line of general and special-purpose analog computers and accessories.—Computer Systems, Inc., 611 Broadway, New York 12, N. Y.

CIRCLE 290 ON READER-SERVICE CARD

MAGNETIC TAPE LOOP TRANSPORTS 4-page Specification DS 3191 describes three instrumentation-grade transports for memory, time delay, wave analyses, etc.—Minneapolis-Honeywell Regulator Co., 10721 Hanna St., Beltsville, Md.

CIRCLE 291 ON READER-SERVICE CARD

TAPE PREPARATION AND EDITING CONSOLE. 6-page Brochure TRC-M1501 illustrates and specifies Model 150 editing unit.—Tally Register Corp., 5300 14th Ave., N. W., Seattle 7, Wash.

CIRCLE 292 ON READER-SERVICE CARD

DIGITAL BUILDING BLOCKS. 4-page folder on "3000 Series DEC Digital Test Equipment" describes new building blocks which operate at speeds up to 500 kc.—Digital Equipment Corp., Maynard, Mass.

CIRCLE 293 ON READER-SERVICE CARD

TRANSISTORIZED COMPUTER. 2-page Catalog Sheet S-482 contains complete specifications on the *RPC-4000* electronic computing system.—Royal McBee Corp., Data Processing Div., Westchester Ave., Port Chester, N. Y.

CIRCLE 294 ON READER-SERVICE CARD

SHAFT ENCODER. 2-page Bulletin 001 describes the C-100 Series shaft encoder with arabic-decimal to cyclic decimal conversion and binary coding. —Datex Corp., 1307 S. Myrtle Ave., Monrovia, Calif.

CIRCLE 295 ON READER-SERVICE CARD

TESTING

MOBILE DC TESTER. 2-page Bulletin 5-60.3 tells how a major sheet and tin mill uses a d-c high potential test set for preventative maintenance of power distribution cables and other electrical gear.—Associated Research, Inc., 3777 West Belmont Ave., Chicago 18, Ill.

CIRCLE 296 ON READER-SERVICE CARD

TEST EQUIPMENT. 6-page brochure illustrates and describes eighteen different machines for use in the paper and paperboard field.—Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

CIRCLE 297 ON READER-SERVICE CARD

WALK-IN SPACE CHAMBERS. 4-page brochure describes features and capabilities of walk-in space chambers and pictures many applications.—Tenney Engineering, Inc., 1090 Springfield Rd., Union, N. J.

CIRCLE 298 ON READER-SERVICE CARD

TEST INSTRUMENTS AND SYSTEMS. 12-page 1959 Short-Form Catalog contains illustrations and descriptions of equipment for testing electronics, microwaves, radomes, antennae; also flight simulation.—California Technical Industries, Div. of Textron Inc., 1421 Old County Rd., Belmont, Calif.

CIRCLE 299 ON READER-SERVICE CARD

RELAYS, SWITCHES

METER-RELAYS. 12-page catalog jointly issued with Voltron Products, South Pasadena, Calif., describes locking contact meter-relays with dimensional sketch and circuitry.—Assembly Products, Inc., Chesterland, Ohio.

CIRCLE 300 ON READER-SERVICE CARD

BINARY THUMBWHEEL SWITCH. 2-page catalog sheet provides description, illustrations, and dimensional drawings of Series TSB modular binary thumbwheel switches.—Chicago Dynamic Industries, Inc., Precision Products Div., 1725 Diversey Blvd., Chicago 14, Ill.

CIRCLE 301 ON READER-SERVICE CARD

MISCELLANEOUS

TRANSMITTING ROTAMETERS. 4-page Bulletin 18N describes pneumatic transmitting rotameters with Model 58 transmitters.—Schutte and Koerting Co., Instrument Div., Dept. M-Q, Cornwells Heights, Bucks County, Penna.

CIRCLE 302 ON READER-SERVICE CARD

PLASTIC-TUBING STRIPS. 6-page Bulletin 110 contains description and full-size profiles of Strip-a-Tube multi-cell flexible vinyl tubing.—Jessall Plastics Div. of Electric Storage Battery Co., Kensington 3, Conn.

CIRCLE 303 ON READER-SERVICE CARD

LIQUID ANTI-STATICS. 4-page 1960 Data Sheet No. 5 describes 2 liquids which remove static electricity.—Merix Chemical Co., 2234 E. 75th St., Chicago 49, Ill.

CIRCLE 304 ON READER-SERVICE CARD

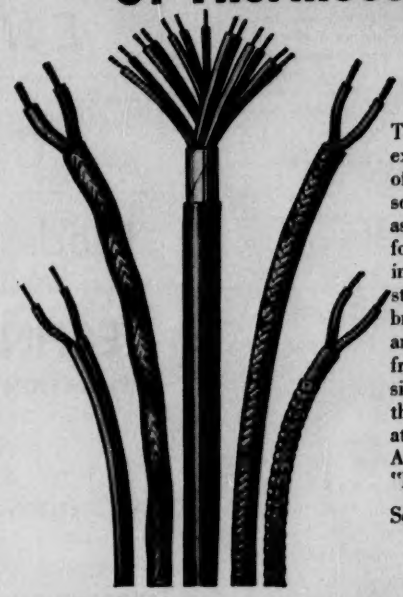
VOLTMETER. 2-page bulletin covers features of the Model R-2 voltmeter for measuring regulation of power supplies, resolution of potentiometers, or linearity of amplifiers.—Southwestern Industrial Electronics Co., a div. of Dresser Industries, Inc., 10201 Westheimer, Box 22187, Houston 27, Texas.

CIRCLE 305 ON READER-SERVICE CARD

HIGH-VELOCITY SPRAY TECHNIQUE 8-page booklet describes the spray-clean technique for transistors, diodes, vacuum tubes, jewel bearings, pivots, electrical contact points, miniature slip-ring assemblies, and other electronic precision parts.—Cobehn, Inc., Passaic Ave., Caldwell, N. J.

CIRCLE 306 ON READER-SERVICE CARD

Choose From The Widest Variety Of Thermocouple Wires



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T-E's tremendous variety of thermocouple extension wires assures you quick delivery of every type and size—from one reliable source. Dependable quality control is also assured by T-E's own complete facilities for wire drawing, insulating and calibrating. T-E duplex wires come in solid or stranded construction, in all standard calibrations. The latest types of insulation and metallic armor overbraid protect them from all atmospheric, chemical and abrasive conditions. From 6 to 56 pairs of T-E thermocouple leads can now be installed at one time with the new "Thermo-Cable". Also available—a complete selection of "MIL"- Spec Wire.

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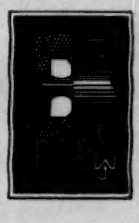
CIRCLE 148 ON READER-SERVICE CARD

bearings and orifices



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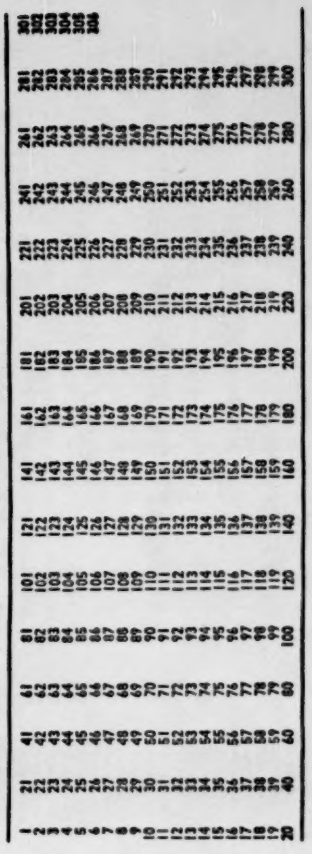

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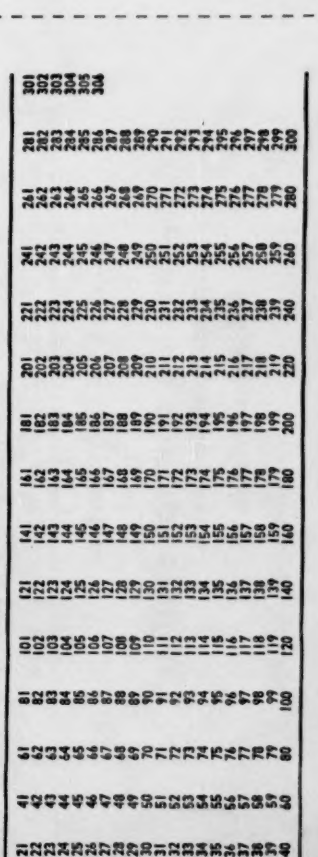

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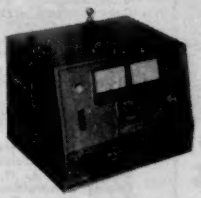

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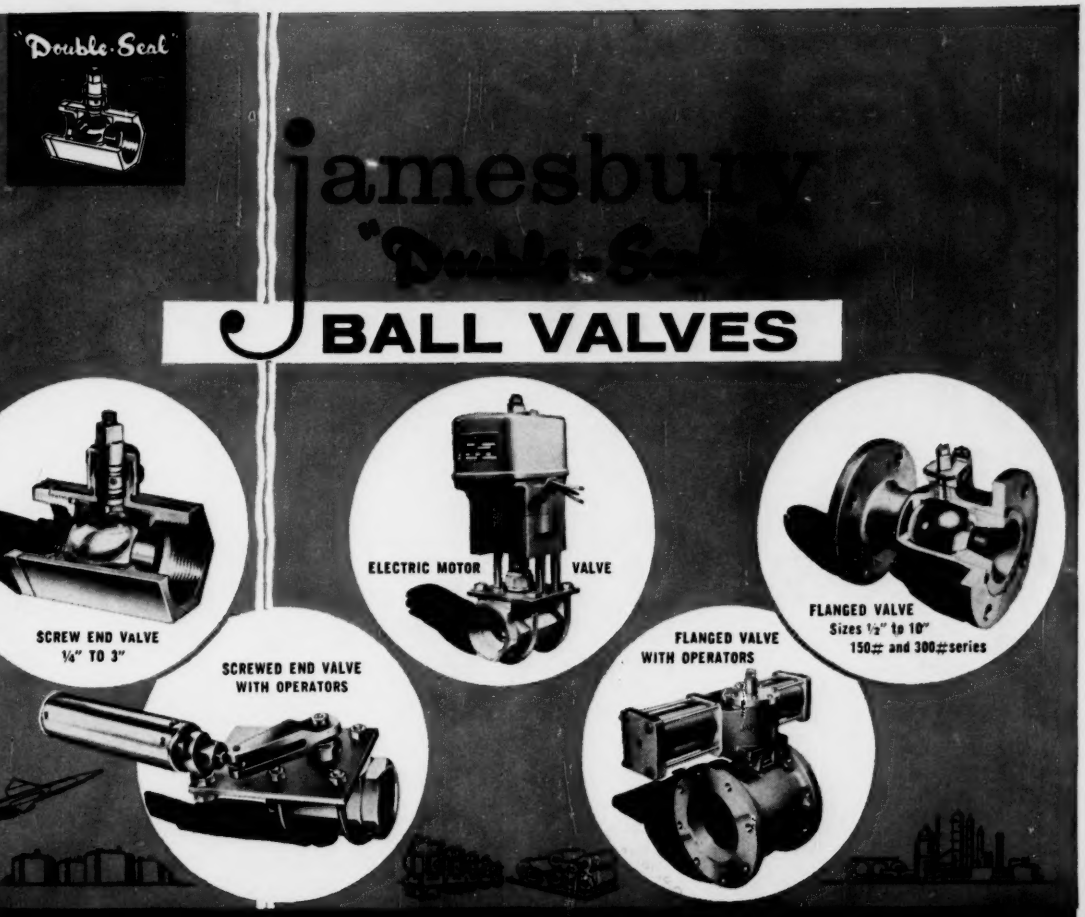

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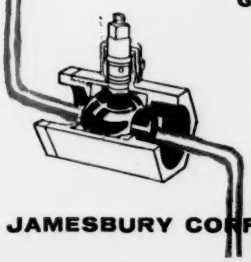

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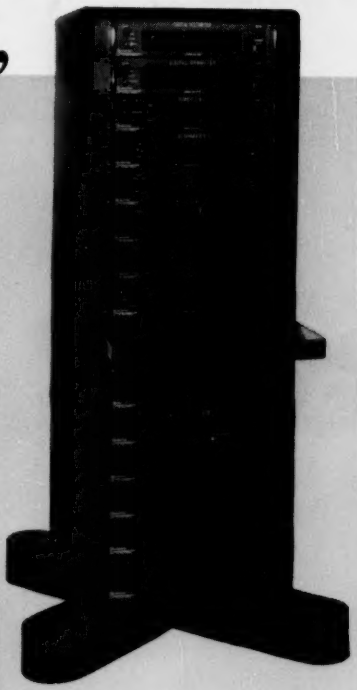
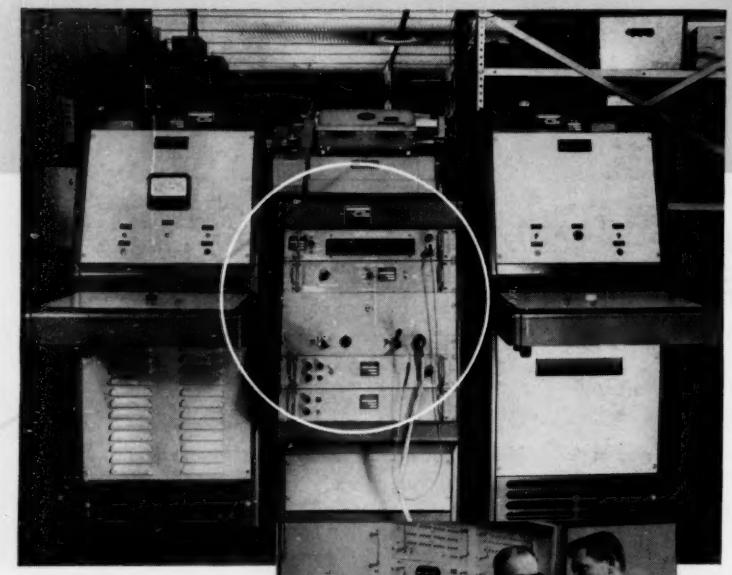
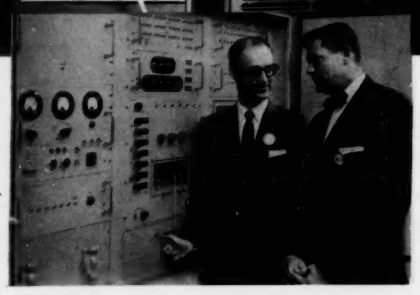
Why not talk over your digital system requirements with your EI Sales Engineer? His system experience will be a valuable help in solving your problem.



Multi-purpose digital system for measuring a variety of transistor parameters while the transistors are being subjected to environmental testing.



Digital read-out sub-system of a large, automatic, transistor production checkout system.



Sub-system for the ground support equipment on the B-58 **Hustler** program. Measures AC and DC single-ended voltages and ratios, and AC and DC differential voltages and transients. Chosen for its excellent operating characteristics under adverse environments.

you get MORE with EI systems!

MORE VERSATILITY—AC and DC voltages, AC and DC voltage ratios, ohmic resistances, capacitance, frequency, phase, inductance, time, or combinations of these basic input quantities can be accepted by the EI system.

MORE RELIABILITY—Maximum use is made of solid-state and MIL-type components which are designed into conservatively-rated, field-proven circuits. All vendor-supplied parts are exhaustively tested and evaluated.

MORE FLEXIBILITY—Expansion of the EI system can be made by simply adding appropriate new modules. This approach eliminates new engineering development costs each time needs change; minimizes system obsolescence.

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